Interim Draft

Regional Nearshore and Marine Aspects of Salmon Recovery in Puget Sound

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1. INTRODUCTION

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Shared Strategy for Puget Sound has convened a broad effort to prepare a recovery plan for Puget Sound salmon and bull trout. Participants in this effort share a vision of self-sustaining harvestable Puget Sound salmon. While we recognize the perilous nature of the current situation, we share the hopeful spirit embodied in this vision of the region's future. We have worked with Shared Strategy staff, technical advisors, and a policy advisory group (aka the Nearshore Policy Group or NPG) to develop this background document on nearhore and marine aspects of salmon recovery. We hope it will be a meaningful contribution to the Shared Strategy's recovery planning effort.

1.1 Statements of premise: our basis for planning nearshore and marine aspects of salmon recovery

We assert that the Puget Sound region's salmon recovery efforts must include attention to nearshore and marine environments because:

- The viability of Puget Sound salmon and bull trout must be improved. Puget Sound chinook salmon (*Oncorhynchus tshawytscha*), Hood Canal summer chum salmon (*Oncorhynchus keta*), and Coastal and Puget Sound bull trout (*Salvelinus confluentus*) are listed as threatened under the federal Endangered Species Act (ESA). This designation reflects a scientific and policy conclusion that biologically significant groups of these fish are at risk of becoming endangered (i.e., in danger of extinction throughout all or a significant portion of their range) in the foreseeable future and that existing management efforts are not sufficient to address this threat.

- Salmon and bull trout, including the species groups designated as threatened, rear in and move through Puget Sound's nearshore and marine environments year-round and rely on these environments to complete their life cycle. Nearshore and marine environments support today's salmon and bull trout populations; they will also be needed to support the recovered populations of the future.

- Nearshore and marine environments of Puget Sound have been greatly altered from their condition prior to settlement of the Puget Sound region by people of European descent. The loss of habitat functions resulting from these alterations is thought to be one factor in the decline of the region's salmon and bull trout populations.

- Puget Sound environments will be altered further as the region's human population continues to grow. Alterations to support new industrial, commercial, and residential activities and development could lead to additional degradation of nearshore and marine habitats as the Puget Sound shoreline continues to be the focus of land development and an intensification of human activities.

We further assert that a regional evaluation of the nearshore and marine aspects of Puget Sound salmon recovery is needed to account for the mingling of populations along the shore and in the waters of Puget Sound. This document reflects our pursuit of this regional evaluation as a complement to the local watershed-scale and population-focused planning around which Shared Strategy is built. Shared Strategy's approach to recovery planning emphasizes the development of plans for protection and restoration at the scale of the watersheds, many of which are home to independent populations of Chinook salmon. Planning at that scale is logical to encourage a focus on the viability of individual populations but is not optimal for understanding recovery needs and strategic opportunities across the nearshore and marine landscape where fish from multiple populations intermingle.

In addition to the two assertions presented above, our efforts to develop this document as a contribution to the Shared Strategy recovery plan were also guided by the following premises:

- A variety of ongoing protection and restoration initiatives in the region can be adapted to support salmon recovery. The State of Washington, local and tribal governments, federal agencies, and a diversity of non-governmental organizations, have developed programs and projects to positively affect the future landscape and environmental conditions in and around Puget Sound. A few of these initiatives are focused specifically on salmon conservation or recovery, but most of them are more general or reflect a different specific focus. Nearshore and marine aspects of salmon recovery in the Puget Sound region will be most effective and efficient if it can build upon the authorities and capacities of these existing efforts.

- A management approach that combines (elements of) the precautionary principle and adaptive management will allow us to preserve options for the future, make wise use of limited resources, and develop and apply new information to improve recovery strategies and actions over time. The Puget Sound Technical Recovery Team (TRT) and Shared Strategy watershed guidance encourages the development of a monitoring and adaptive management plan (i.e., learning-evaluation-adaptation cycle) as an element of a salmon recovery plan. The TRT's evaluation of draft recovery plan chapters (e.g., December 20, 2004 comments on a draft regional nearshore chapter) suggests that we can preserve options in our approach to salmon recovery (and thereby increase the certainty of recovery) if we: (1) protect existing salmon viability and opportunities to improve conditions in the future; and (2) develop and implement a program of monitoring and adaptive management.

1.2 The scope and scale of our effort

The scope of this document can be delimited along dimensions geographical and biological scope (what area? which fish?) and scale (what are the units of analysis?). Our efforts to build this document were constrained along each of these dimensions.

Geographical and biological scope. The Puget Sound basin encompasses the entire evolutionary significant units (ESUs) for Puget Sound chinook salmon and Hood Canal summer chum salmon, as well as a significant portion of the Distinct Population Segment (DPS) of Coastal-

Puget Sound bull trout. This chapter focuses on recovery of these three groups of fish, and most of the analyses and attention are focused on Chinook, as they rear in and migrate through the nearshore and marine areas of the Puget Sound basin (Figure 1-1). While the basin includes U.S. and Canadian shorelines and waters, we restricted our analyses to only the U.S. portion of the basin.

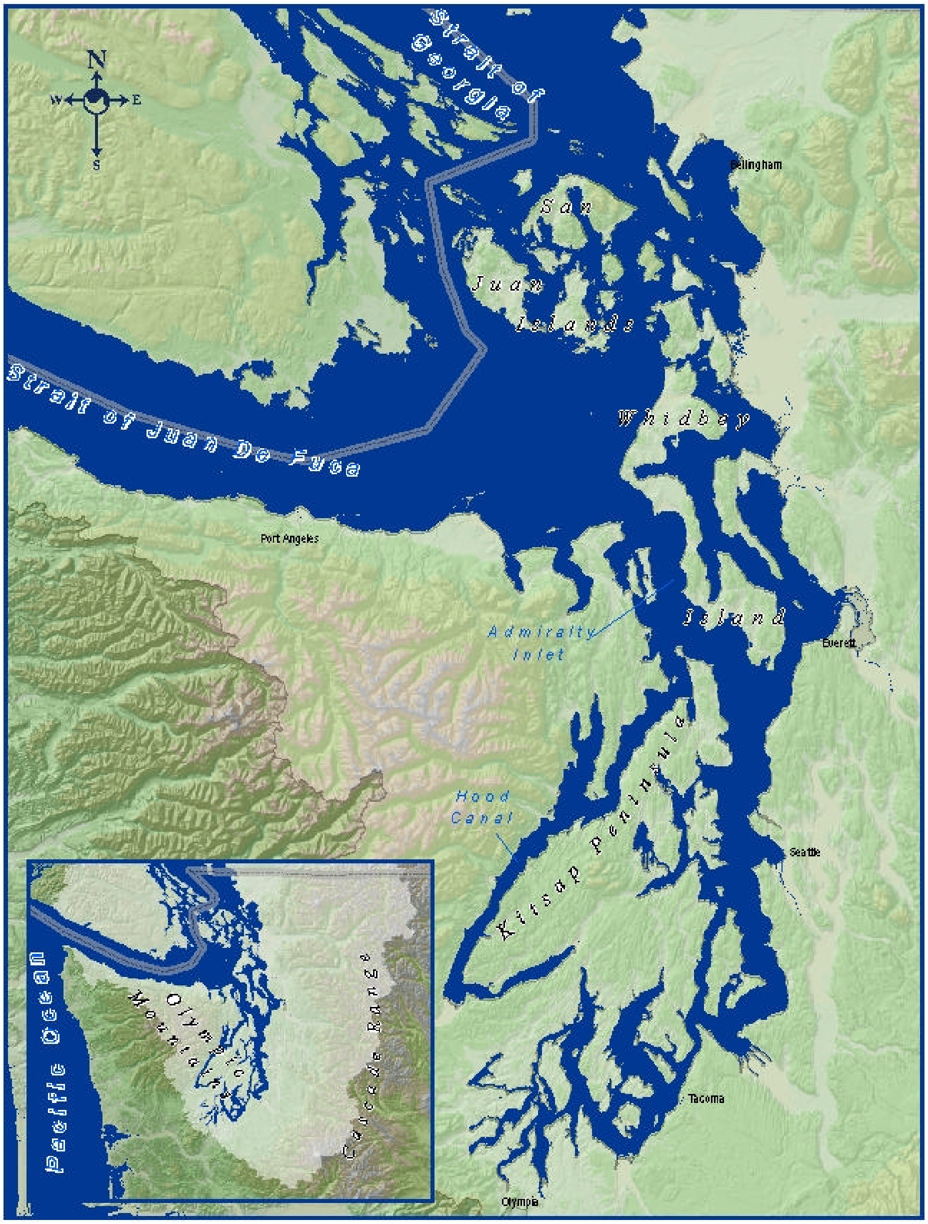


Figure 1-1: Puget Sound (inset is Puget Sound Basin)

This document does not specifically address the nearshore and marine life stages of other salmonids. The three groups of fish designated as threatened and specifically evaluated in this document, are among the salmon species most dependent on regional nearshore and marine resources for rearing as outmigrants (Chinook and chum) and as resident sub-adults or adults (Chinook and bull trout). (Citation?)

For this document we define nearshore as the zone of interface among the open waters of Puget Sound, the freshwaters of rivers and streams, the air, and the land. The aquatic portion of the nearshore extends up rivers and streams to the upstream limit of tidal influence, along the shoreline at the line of extreme high water, and out to the 20 meter bathymetric contour, which we mean to include the area of marine bedlands that receive sufficient sunlight to (potentially) support the growth of attached algae. The nearshore also includes upland and backshore areas that directly influence conditions in this aquatic region. This chapter also deals with the deeper marine waters of Puget Sound, defined to include all the waters connected to the Pacific Ocean through the straits of Juan de Fuca and Georgia.

Scale. The scale of the analysis used in developing this chapter is more fully described later sections, but some key features are identified here:

- The listed units or segments of chinook, chum, and bull trout are described in sub-units of population (i.e., 22 independent populations of Puget Sound Chinook salmon and eight populations of Hood Canal summer chum) or core area (i.e., 11 of the 14 core areas of the Coastal-Puget Sound DPS occur in what we define as the Puget Sound region). Although we acknowledge the significance of the population as the unit for measuring viability (see Section 2), we have not conducted extensive analysis at this level of detail. The populations and core areas are introduced in Section 3.

- Where applicable, we analyzed distinct life history trajectories related to the (early stages of the) marine portion of the anadromous life cycle of these fish. The life history trajectories used in this documents are introduced and discussed in Section 3.

- The landscape of Puget Sound's nearshore and marine environments can be viewed and analyzed at various scales. In this document, we develop and apply a subdivision of Puget Sound nearshore and marine environments into marine sub-basins, landscape classes, and habitat features. These subdivisions are introduced in Section 2.

1.3 The conceptual basis for our assessment and recovery hypotheses and strategies

One of us (Fresh) has proposed a conceptual model[1] of salmon interactions with nearshore and marine ecosystems as they are influenced by people. This model frames and organizes our work to assess the current situation and develop recovery hypotheses and strategies. Our adaptation of this model (Figure 1-2) indicates how salmon and bull trout population viability depends on and is affected by ecosystem processes, the resulting habitat attributes, and human-related stressors that can impair these processes or habitats.

[1] Based upon an ecosystem-based model that is being used to organize and structure research efforts by the Watershed Program at the Northwest Fisheries Science Center (Beechie et al., 2003).

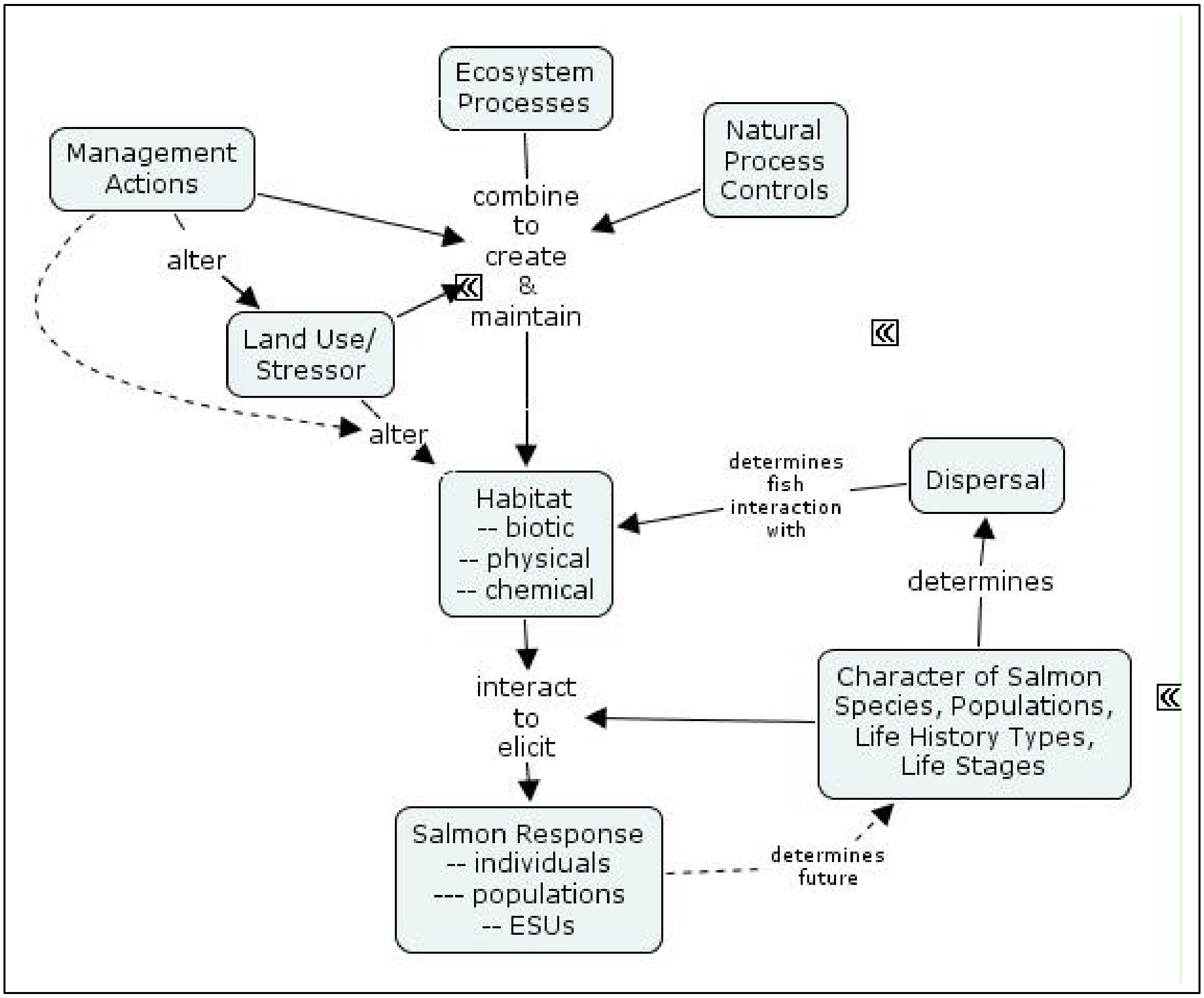


Figure 1-2: Conceptual model of nearshore and marine aspects of salmon recovery

The upper right and center portion of the model depicts connections among nearshore and marine ecosystem processes and natural controls on these processes, and the physical, chemical, and biological habitat features available to support salmon and bull trout in Puget Sound nearshore and marine environments. Our elaboration on this portion of the model in Section 2 emphasizes that nearshore and marine habitat features arranged on the landscape of Puget Sound reflect, and result from, the interplay of ecosystem processes (e.g., movement of fresh water, ocean water, sediment, and organic material) and natural controls on these processes (e.g., global climate and ocean variability, geomorphology).

The lower right portion of the model depicts relationships among habitat features and the dispersal and response of salmon individuals and populations. This section of the model emphasizes the interplay of the diversity of salmon (reflected in differences among species, populations, and within populations) and the nearshore and marine habitat features they (might) access to support their growth and survival. Section 3 of this chapter provides a detailed review of salmon-habitat relationships in Puget Sound nearshore and marine environments.

The upper left portion of the model describes how human land uses and human activities (stressors and management activities) can affect nearshore and marine ecosystem processes and habitat features. Specific connections from this area of the model to the salmon portion of the model are described in Section 4 of this chapter; these relationships between the realms of human activity and salmon population response suggest avenues by which humans can positively and negatively influence salmon and bull trout populations.

1.4 Some general goals/strategies for nearshore and marine aspects of Puget Sound salmon and bull trout recovery

Based on the statements of premise and general understandings presented above, the NPG outlined three goals or strategies for the regional nearshore and marine work on Puget Sound salmon recovery:

Goal 1. Protect key nearshore and marine ecosystem features and processes to maintain the viability of salmon and bull trout populations while also supporting other interests that depend on the marine shorelines and waters of Puget Sound.

Goal 2. Restore and enhance key nearshore and marine ecosystem features and processes to improve the viability of salmon and bull trout populations while also supporting other interests that depend on the marine shorelines and waters of Puget Sound.

Goal 3. Increase the certainty of recovery for Puget Sound salmon and bull trout populations by improving the body of knowledge about salmon and bull trout requirements of nearshore and marine environments and the effects of human activities on these environments and on the viability of the salmon and bull trout.

1.5 Our approach to developing recovery hypotheses and strategies and developing an adaptive management plan

The next sections of this document:

- provide details about various aspects of our conceptual model of salmon recovery in nearshore and marine environments (sections 2 through 4);
- present our recovery hypotheses (Section 5);
- evaluate salmon-specific needs and protection and restoration opportunities in 11 marine sub-basins of Puget Sound (Section 6);
- present our recovery goals and strategies (Section 7); and
- describe a collaborative process for deciding on actions and instituting an adaptive management process (Section 8).

The information (and uncertainties) developed in sections 2 through 4 of this chapter provide the foundation for specifying recovery hypotheses, which we present in Section 5. These hypotheses highlight and clearly state the key elements of the logical framework that we suggest to achieve salmon recovery. Discussion of these hypotheses also addresses the relative level certainty in the various elements of this framework.

We use these recovery hypotheses to guide a life-stage and spatially-explicit evaluation of the key opportunities to support population and ESU recovery in each of 11 marine sub-basins in Puget Sound. These evaluations, which are presented in Section 6**,** overlay the hypotheses described in Section 5 with a fairly rudimentary characterization of the salmon and ecological and landscape conditions of each sub-basin. By completing these evaluations across the entire landscape of Puget Sound, we see patterns that help us articulate more specific goals and strategies for regional nearshore and marine aspects of salmon recovery.

Sections 2 through 6 then set the stage for our articulation, in Section 7, of recovery objectives following the three goals stated above and building from the accumulated information on nearshore ecosystems and salmon and bull trout populations. We expect that these objectives will be consistent with co-manager derived recovery targets but we do not evaluate this expectation. We understand that it would be optimal to develop and use measurable goals regarding salmon recovery in the nearshore for each sub-basin, but existing information does not allow or justify the development of numeric goals. In Section 7, we also articulate general strategies that will move us toward our goals and objectives by building on a foundation of existing management approaches, recovery hypotheses, and spatially explicit evaluations of opportunities for recovery in Puget Sound nearshore and marine environments.

Finally, in Section 8 we propose an approach to adaptively develop and manage a 10-year (and longer) action plan to address nearshore and marine aspects of Puget Sound salmon recovery. Unlike the local chapters of the regional recovery plan, we have not attempted to include a 10-year action plan, including commitments to implement actions, in this document. Instead, we describe a suite of very near term actions that are already underway to advance the strategies and suggest a collaborative process for developing a plan for 10-years (and longer) that presumes continued learning and adaptation of hypotheses, strategies and actions. We have pursued this course because:

- Our work to develop the technical basis for our recovery hypotheses and strategies has continued into April 2005;
- We have not yet succeeded in convening or consulting with the decision-makers who might have the authority and resources to enact many of the ideas we are suggesting; and
- Identification of region-scale priorities and actions should address issues beyond nearshore and marine aspects of salmon recovery.

2. PUGET SOUND NEARSHORE AND MARINE ECOSYSTEMS: PROCESSES, LANDSCAPES, HABITATS

Dan Averill and Doug Myers, Puget Sound Action Team
Bill Graeber, NOAA Fisheries

In this section, we describe (1) the relationship between ecosystem processes, landscapes and habitats in nearshore and marine environments and (2) the major regions and subdivisions of Puget Sound nearshore and marine ecosystems that we have used for salmon recovery planning. These subsections address the portion of the conceptual model highlighted in Figure 2-1.

Subsection 2.1 provides information about how nearshore and marine ecosystem processes create and maintain features that support a variety of ecosystem functions. Subsection 2.2 provides information about our approach to defining and delineating sub-basins. Subsection 2.3 provides information about the landscape classes selected for analysis within the nearshore and marine portion of the Sound. Subsection 2.4 presents a set of major uncertainties and data gaps.

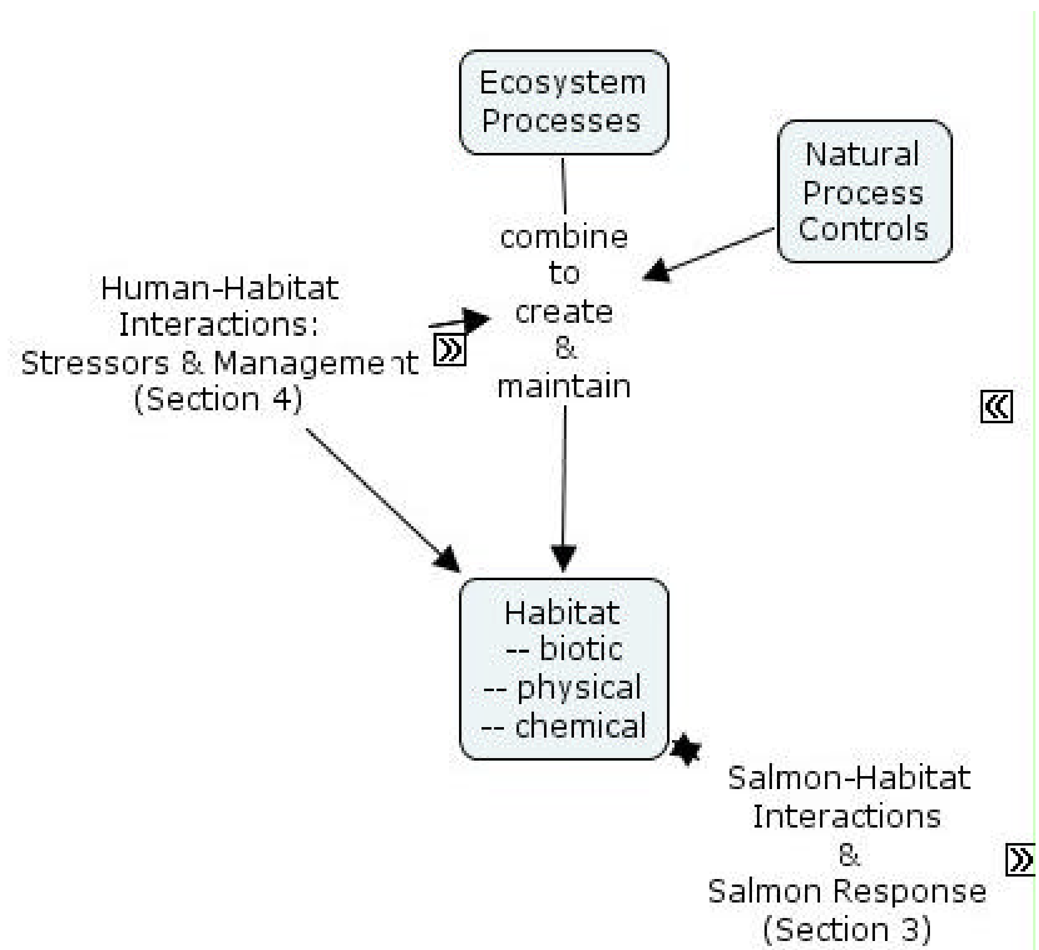


Figure 2-1. The ecological process-habitat portion of our conceptual model

Physical Description

Puget Sound and the associated inland marine waters of northwest Washington State are a large estuary complex, carved by glaciers, receiving runoff from the encircling Cascade and Olympic mountains, and connected to the Strait of Georgia and the western north Pacific Ocean through the Strait of Juan de Fuca. For this chapter, we refer to the U.S. portion of the straits of Juan de Fuca and Georgia and the marine waters landward of them as Puget Sound (see Figure 1). Using this definition, Puget Sound includes Hood Canal, the bays and passages east of Whidbey Island (aka the Whidbey Basin), Admiralty Inlet, the straits and passes around the San Juan Islands, as well as the waters Puget Sound proper including the bays and inlets of the eastern Kitsap peninsula and south Puget Sound.

Made up of a series of underwater valleys and ridges called basins and sills, Puget Sound is deep, with an average depth of 450 feet. The maximum depth of 930 feet occurs just north of Seattle. A relatively shallow sill at Admiralty Inlet separates the waters of the Strait of Juan de Fuca from the waters of Puget Sound proper. Puget Sound is surrounded by approximately 2,500 miles of shoreline, a mosaic of beaches, bluffs, bays, estuaries, mudflats and wetlands.

The waters of Puget Sound reflect a mixing of salt water from the ocean with fresh water that falls as precipitation or drains from the surrounding land. More than 10,000 streams and rivers drain into Puget Sound. Nearly 85 percent of the basin's annual surface water runoff comes from 10 rivers: the Nooksack, Skagit, Snohomish, Stillaguamish, Cedar/Lake Washington Canal, Green/Duwamish, Puyallup, Nisqually, Skokomish and Elwha.

2.1 Key nearshore and marine ecosystem processes

Giant ice sheets moving over northern North America over thousands of years created the geologic and geomorphologic template onto which Puget Sound's landscape is drawn. Oceanic and atmospheric circulation in and over the Pacific Ocean define the general character and decadal and interannual variability of climate conditions that drive the hydrologic cycle and prevailing winds in the Puget Sound basin. Predictable tides and winds, both prevailing and variable, overlay a general pattern of freshwater-driven estuarine circulation[1] to distribute low salinity water, nutrients, organic matter, and organisms through the basins, bays, and channels of Puget Sound.

These are some of the many interconnected processes that act, at different spatial scales and over different time periods, on the nearshore and marine environments of Puget Sound. Bauer and Ralph (1999) invoke hierarchy theory to suggest that "ecosystem processes and functions operating at different scales form a nested interdependent system where one level influences other levels above and below it." To further explain the relationship between process and scale, Bauer and Ralph (1999) use definitions of Naiman et al. (1992) to describe two types of controls on ecosystem processes.

[1] Freshwater, which is buoyant relative to the denser high-salinity waters of the Sound and ocean, flows ocean-ward from river mouth estuaries. By entraining some marine waters from deeper in the water column into this ocean-ward surface flow, the freshwater discharge drives a landward flow of denser oceanic waters at depth. Estuarine circulation, absent the influence of tidal and wind driven current, would be characterized by this vertical system of shallow, fresher outflow and deeper, saltier inflow.

- Ultimate controls are "factors that operate over large areas, are stable over long time periods (hundreds to thousands of years), and act to shape the overall character and attainable conditions within" a system.

- Proximate controls "are a function of ultimate factors and refer to local conditions of geology, landform and biotic processes operating over smaller areas (e.g. reach scales) and over shorter time spans (decades to years).

Principles and concepts of landscape ecology (e.g., Turner 1989) are being applied in restoration of freshwater habitats for salmonids (Roni et al. 2002) and in the evaluation of functions of nearshore systems (e.g., Hood 2002). Simenstad (2000) discussed juvenile salmon integration at large landscape scales in an assessment of the Commencement Bay aquatic ecosystem in central Puget Sound. He described three landscape elements important to salmon and salmon recovery in an estuarine landscape: 1) *patches* ("non-linear surface areas, relatively homogeneous internally…that differ in appearance from surrounding matrix in which they are imbedded," characterized by several variables and determined by a combination of several processes; can be referred to as habitats), 2) *matrix* ("surrounding area that has a different composition or structure from embedded patches; the most extensive, connected element in the landscape") and 3) *corridors* ("narrow strip of land (or water) that differs from the matrix on either side;…can also be considered a narrow and often long patch that provides a connection between two or more similar patches").

Applying the concepts of hierarchical relationships of processes and scales and landscape ecology to nearshore and marine aspects of salmon recovery we follow Simenstad's (personal communication with K. Fresh, NOAA-Fisheries) identification of three relevant scales of processes operating in Puget Sound:

- <u>Regional or large-scale processes</u> – such as plate tectonics with ensuing earthquakes and volcanic eruptions, circulation of the ocean and atmosphere with ensuing climatic events – influence all ecosystems across scales of tens to hundreds of kilometers and often produce dramatic, intense change. Climate is especially important because, to some degree, all processes are controlled by climate. Decadal scale shifts in climate are related to shifts in the abundance and distribution of fauna and prey species, and over broad regions, this can result in substantial reorganizations of ecological relationships (Francis and Hare, 1994). Regional processes can dramatically alter the physical template of Puget Sound and can not be manipulated or changed at a local scale (e.g., Puget Sound), but are nevertheless important to understand because they help control or regulate processes occurring at smaller scales.

- <u>Local or landscape-scale processes</u> are embedded within the large-scale influences and so occur at scales of kilometers or fractions thereof. Local processes include estuarine circulation of fresh- and oceanic water; sloughing, slumping, and sliding of bluffs; longshore drift of sediments; and food web interactions.

- <u>Finite or small-scale processes</u> vary at the scale of meters or fractions thereof and involve highly variable geochemical and biological processes, such as nutrient transformation in sediments and primary production by algae or eelgrass, and water column clearing and benthic transfers of nutrients and organic matter through filter feeding.

We focus especially, but not exclusively, on the landscape scale because:

- Salmon integrate with the landscape over large spatial and temporal scales as a result of a multi-year life cycle that relies on functions from freshwater and marine systems, and includes transition between and, often, considerable movement within both environments; and

- Many of the most important physicochemical and biological processes necessary to sustain functioning habitats occur at a landscape scale.

Goetz et al. (2004) hypothesize that "alterations of natural hydrologic, geomorphologic, and ecological processes impair important nearshore ecosystem structure and functions." We believe that it is reasonable to extend this hypothesis to nearshore and marine aspects of salmon recovery, particularly as the condition of landscapes and habitat features can either support or inhibit the viability of salmon and bull trout populations. Thus, our conceptual model directs us to the development of recovery hypotheses, strategies, and actions that focus on hydrologic, geomorphic, and ecological processes acting at the landscape, regional, and finite scales.

Simenstad (2000) identifies disturbance as an additional landscape-scale process. Rather than treating this as a process, we follow Bauer and Ralph (1999) in discussing natural, pulse disturbance events as a control on ecosystem processes. We discuss press disturbances (Bauer and Ralph 1999) of human origin as stressors (see Section 4.) Diverse mosaic of habitats across the landscape is created and maintained by the sporadic occurrence of events such as: extreme storms or runoff events leading to, for example, mass wasting of bluffs; and fires or volcanic events leading to, for example, changes in the recruitment of large woody debris (Simenstad 2000, Bauer and Ralph 1999).

The role of landscape-scale ecosystem processes in creating and maintaining the landscape and mosaic of nearshore and marine habitats in Puget Sound is discussed in Section 2.3. In Section 4, we discuss human stressors that impair or threaten these processes and natural controls on these processes in the Puget Sound basin.

2.2 Regions and sub-basins

Because of the large size and considerable heterogeneity of marine and nearshore environments in Puget Sound, we designed our evaluation of nearshore and marine landscapes and ecosystem processes to address sub-basins within the region and landscape classes and features within these sub-basins. Landscape classes and features are discussed in Section 2.3.

Our fundamental hypothesis in dividing Puget Sound into smaller pieces is that salmon utilization of different regions of Puget Sound varies according to differences in geomorphic context (e.g., landform) and oceanographic conditions. Such differences in oceanographic conditions and geomorphology help define patterns of habitat use, diet, residence time and so on, and are also important determinants of the processes that create and maintain habitat in each region.

Our subdivision of Puget Sound began with the NOAA-TRT's delineation of five geographic regions of diversity and correlated risk for Puget Sound Chinook (Figure 2-2). This delineation is one of many possible approaches to subdividing the marine waters of Puget Sound. We used the TRT approach because it (1) is specifically designed to inform recovery planning and (2) has marine boundaries generally consistent with those identified by others and already in use for ongoing programs (PSAT 2002a).

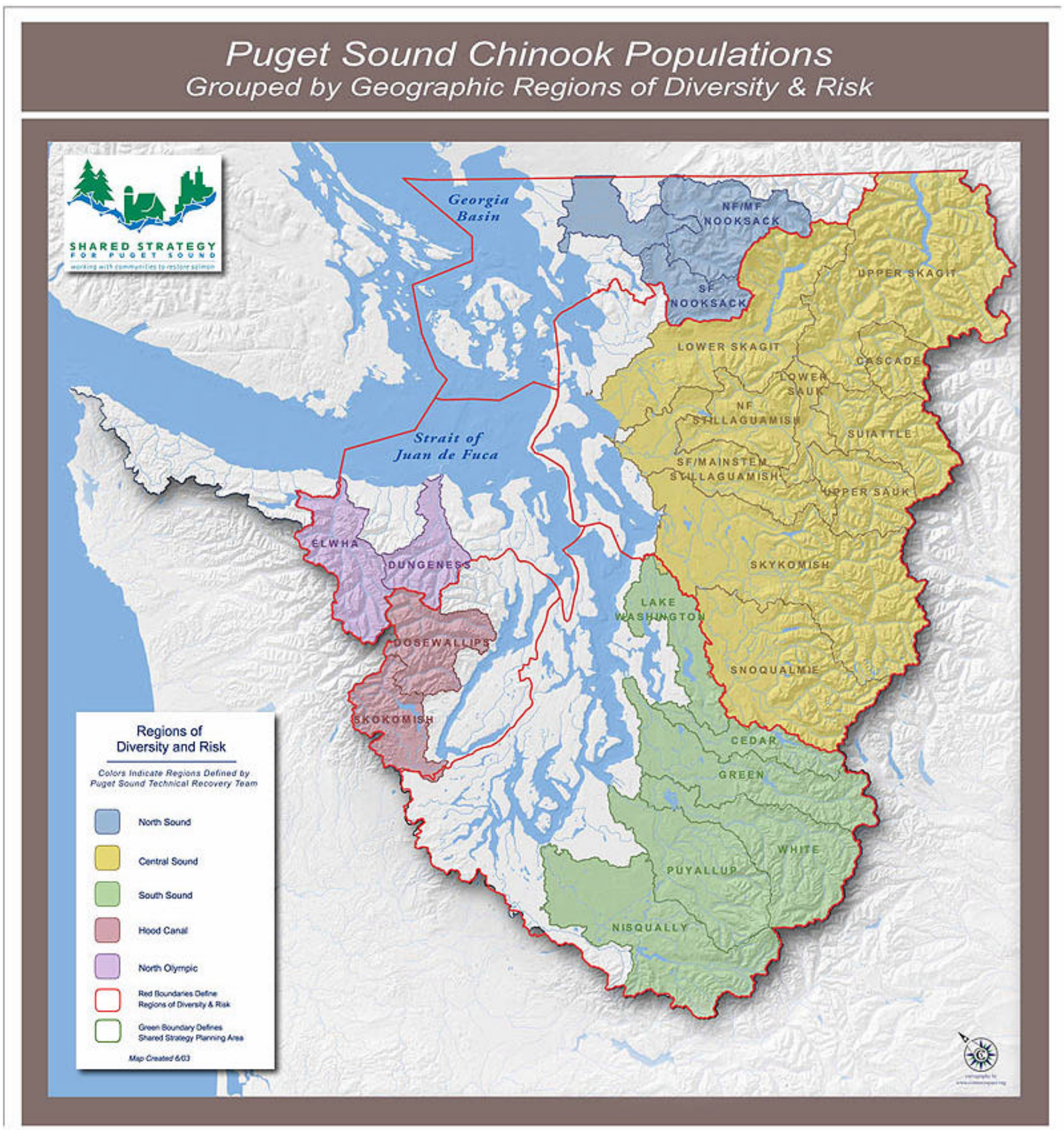


Figure 2-2. Five geographic regions of diversity and correlated risk for Puget Sound Chinook.[S2]

The TRT definition of five geographic regions within the Puget Sound basin reflects a synthesis of prior delineations of:

- marine basins (per Ebbesmeyer et al. 1984 cited in PSAT 2002a),
- terrestrial ecoregions (Omernik & Bailey 1997), and
- genetic diversity units of Puget Sound Chinook salmon stocks (citation?).

We considered assessing and evaluating the marine areas of each of these regions but decided instead to further subdivide some of these areas to describe and address more homogeneous marine basins. We accomplished this by adapting Ebbesmeyer et al. (1984) and PSAMP (PSAT 2002a) delineations of marine basins, which follow oceanographic conditions, amount of freshwater inflow and other indicators. This approach yields a system of 11 marine sub-basins (Figure 2-3). [1]

Note that we have not included the western portion of the Strait of Juan de Fuca in our delineations. This is an artifact of our decision to simply subdivide, or use whole, the TRT-defined regions. We understand that our treatment of the Strait of Juan de Fuca should be revised to include (1) the region out to Neah Bay/Cape Flattery and (2) sub-basin boundaries that better follow oceanographic conditions on the Strait.

Based on our definition of nearshore environments (e.g., depths of less than 20 m below MLLW), Puget Sound contains more than 641 square miles of nearshore and more than 1,817 square miles of deeper marine environments. Nearshore and deep water habitats are not evenly distributed among the 11 sub-basins of Puget Sound (Figure 2-3). The Whidbey sub-basin contains the greatest quantity of area classified as nearshore (121 square miles), with 50% of this sub-basin's total area classified as nearshore. Eighty-one percent of the Padilla and Samish Bay sub-basin's total area of 66 square miles is classified as nearshore. Conversely, only 11% of the Eastern Strait of Juan de Fuca sub-basin's total area of 74 square miles is classified as nearshore.

2.3 Landscape Classes

To describe the key nearshore and marine subsystems within Puget Sound's marine sub-basins, we have defined landscape classes that provide a foundation for describing how ecosystem processes form and affect the landscape of Puget Sound and for presenting information in Sections 3, 4, and 6. As used in this chapter, a *landscape class* is a type of environment within a sub-basin that is influenced by a distinct set of ecosystem processes. These landscape classes generally reflect processes that operate at the spatial scale of miles to tens of miles and the time scale of decades and centuries.

[1] In order to analyze the attributes of each of these units (e.g., water quality), it is necessary to define or draw boundary lines between the 11 marine sub-basins we have defined (as shown in Figure 2-4). We suggest that these boundaries should be viewed as "fuzzy" lines because the processes used to delineate the sub-basins do not begin and end at discrete points. Thus, the precise lines shown on Figure 2-4 are less important than their general location and rationale for the selection of the sub-basins as discrete units for evaluation.

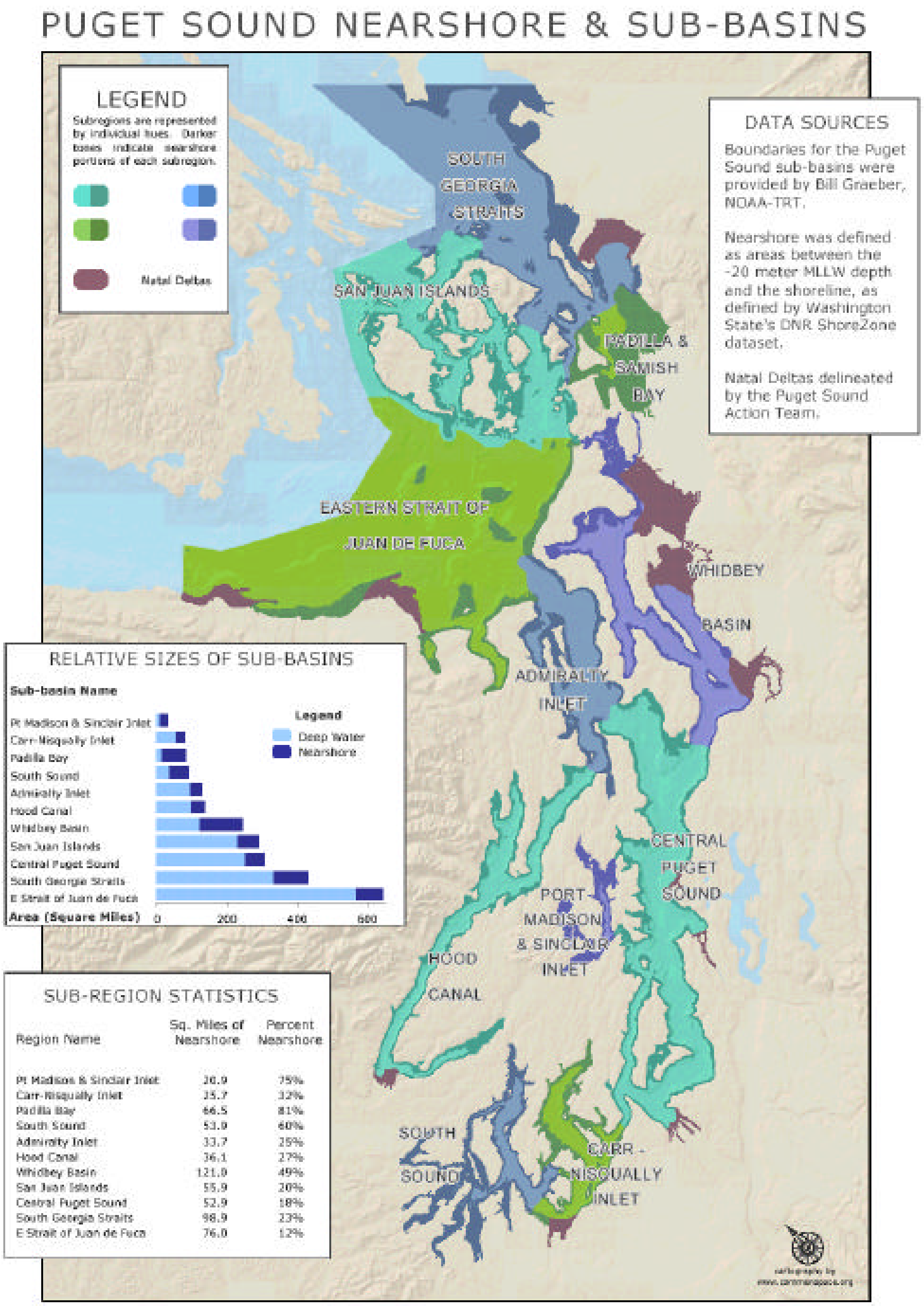


Figure 2-3. **Eleven marine sub-basins and nearshore portions of Puget Sound.** [S3]

Following some of the preliminary decisions from the PSNERP Nearshore Science Team about a habitat typology for nearshore environments in Puget Sound (Shipman et al., in prep.), we describe the nearshore and marine environments of each sub-basin according to four broad landscape classes, including three classes of nearshore environments and one class that captures the deeper waters of a sub-basin:

1. Estuaries
2. Bays
3. Beaches
4. Marine Waters

Each of these landscape classes includes a number of embedded features and smaller scale habitat types, such as lagoons, mudflats, bluffs, spits, eelgrass beds, blind tidal channels, and the water column. Various types of features and habitat types can occur in more than one landscape class. For example, an estuary and a lagoon feature of a beach may each contain emergent marsh and mudflats.

The following paragraphs provide a brief description of each of the landscape classes and examples of occurrences of these classes in Puget Sound. In addition, key features, habitat types, and ecosystem process that characterize each of the landscape classes are discussed.

2.3.1 Estuaries. Within the large estuarine complex of Puget Sound, there are a number of larger river estuaries (e.g., Skagit, Nisqually) and many additional smaller estuaries (Gorst Creek, Ennis Creek). For purposes of this chapter, we define an estuary as the area at the mouth of a river or stream dominated by processes related to the discharge of fresh water. We describe the spatial extent of an estuary as the area from the head of tidal influence seaward to the point where fluvial influences no longer dominate. Table 2-1 lists 23 of the largest estuaries in Puget Sound. The discharges of many smaller rivers and streams also form estuaries where they enter Puget Sound. Key estuaries in Puget Sound are depicted in sub-basin maps in Section 6.

Estuaries occur in a variety of sizes, shapes, and geomorphic settings. Most estuaries include some mix of shallow, dendritic, blind channel networks; backwater, distributary sloughs and small channels; large, main channels with fringing vegetation; and mud/sand flats.

For example, a freshwater drainage (watershed) that extends three to five miles inland that has been carrying sediment toward Puget Sound for several hundred years is likely to create a small estuary. This estuary will likely be evident on the landscape as a network of distributary channels over a deltaic fan.

Processes operating at multiple scales significantly influence features of the habitats within any estuary but the location along the estuarine gradient is especially important (Simenstad 2000). Salinity regimes are a primary determinant of vegetation, invertebrate, and fish community composition, are very dynamic and depend on a variety of factors including tide, riverine inputs, and bathymetry.

Cowardin et al. (1979) developed a system of wetland classification that is often used to describe estuarine habitats. This scheme identifies three discrete habitat zones within estuaries:

1. Tidal, riverine forests and wetlands.
2. Emergent, forested transition (scrub shrub).

Table 2-1. Major estuaries of Puget Sound[1]

Estuary, named for river or stream entering Puget Sound	Drains land of water resource inventory area (WRIA):	Enters Puget Sound at:	Average annual discharge in cubic feet per second (cfs)
Nooksack	1	Bellingham Bay	3810
Skagit	3 and 4	Skagit Bay	16300
Stillaguamish	5	Port Susan	2010
Snohomish	7	Possession Sound	9480
Lake Washington Ship Canal*	8	Salmon Bay/Main Basin	
Duwamish	9	Elliott Bay	1500
Puyallup	10	Commencement Bay	3330
Chambers Creek	12	Nisqually Reach	113
Nisqually	11	Nisqually Reach	1860
Deschutes	13	Budd Inlet	404
Kennedy Creek	Each drains a portion of 14	Totten Inlet	61
Goldsborough Creek		Hammersley Inlet	107
Union	Each drains a portion of 15	Lynch Cove (Hood Canal)	51
Dewatto Creek		Hood Canal	71
Skokomish	Each drains a portion of 16	Great Bend of Hood Canal	1190
Dosewallips		W. shore of Hood Canal	450
Duckabush		W. shore of Hood Canal	428
Hamma Hamma		W. shore of Hood Canal	423
Big Quilcene	Each drains a portion of 17	Dabob Bay of Hood Canal	143
Little Quilcene		Dabob Bay of Hood Canal	52
Dungeness	Each drains a portion of 18	Dungeness Bay	380
Morse Creek		Strait of Juan de Fuca	135
Elwha		Strait of Juan de Fuca	1520

* *This is not a location of significant natural drainage; the landscape and habitats at the mouth of the Ship Canal at Salmon Bay do not reflect the influence of fluvial processes as evident at other estuary locations.*

3. Estuarine, emergent marshes.
4. Estuarine (delta) mudflats or tide flats.

These habitat zones are primarily distinguished by location along the estuarine gradient, which defines salinity regime, patterns of tidal inundation, and thus vegetation type. The tidal riverine zone is located in the upper portion of the estuary, the emergent, forested transition habitat zone occurs in the middle part of the estuary, and the emergent marsh area occurs near the outer delta. The historic reconstruction of major estuaries in Puget Sound by Collins et al. (2003) has shown that each estuary possessed its own unique proportion of each habitat zone and each has been significantly altered in recent time.

The movement of water within the estuary (hydrologic processes) has a fundamental influence on many of the functions of estuary habitats. Within estuaries, water erodes and deposits

[1] Includes all river and stream discharges listed as greater than 50 cubic foot per second annual average discharge (Sinclair & Pitz 1999).

sediments, acquires and transports nutrients and organic matter, and transports fish and prey items. For example, organic matter supporting food webs can be transported from upstream areas and moved around within the estuary. In addition, the shape and complexity of the channel network in any part of the estuary depends upon processes involving water movement, geological and topographical features (e.g., slope, depth, connections to other habitats, size of the system, and landform), which in turn depend upon location within the estuary. Within estuaries, water movement occurs as a result of river flows, tides, and waves. The acquisition and transport of sediments by water within estuaries helps shape deltaic habitats. An important source of sediments in estuaries is upstream of the estuary from the watershed.

As in freshwater reaches of rivers, deltaic channel structure is forced by fluvial processes operating on large woody debris and sediment (Collins et al. 2003). Nearshore processes also operate on large woody debris to similarly create fine scale habitat features, such as pockets and bars, in estuaries (Gallagher 1979).[S4]

2.3.2 Bays. While geographers have assigned the name "bay" to all kinds of semi-enclosed waterbodies, we define this landscape class as shoreline reaches characterized by limited wave action, often resulting from limited exposure to winds. Tidal flows and circulation are the dominant processes that create and maintain habitats in bays. As a result, bays are typically areas of some shallow water and low velocity, where tidal processes are especially important to delivery and movement of fine sediments.

Bays are subject to less wave and current energy than the open shorelines of beaches (discussed below) and less influenced by freshwater input than estuaries. If a bay is relatively large (e.g., Commencement Bay) and includes some areas of greater exposure to wind waves, beaches (the third landscape class) could be nested within it. Freshwater input and influence in bays varies, but most bays in Puget Sound receive freshwater inputs from estuaries and, therefore, have some areas of lower salinities.

Examples of bays in Puget Sound include Discovery Bay, Commencement Bay, Budd Inlet, and Hammersley Inlet. The protected shorelines of bays include geographic regions of Puget Sound such as Camano Island and the east shore of Whidbey Island.

Types of nearshore habitats occurring in bays may include:

- Non-vegetated mud flats (gentle slope),
- Non-vegetated steep slopes,
- Eelgrass meadows,
- Fringing eelgrass,
- Fringing kelp,
- Rock – kelp (e.g., interior San Juan Islands),
- Marshes
- Riparian[S5]

Bay shorelines, because of the limited wave action, often contain marine riparian zones or shorelines with overhanging vegetation. These marine riparian zones are important transition areas between the terrestrial, freshwater, and marine ecosystems, contributing to the health of the nearshore ecosystem and providing functions such as protection of water quality, shade, bank stability, and input of nutrients and large woody debris (Williams *et al*. 2001). For example, shading can be important for managing water temperatures in tidal channels, streams or seeps; vegetation and intact soils of riparian areas can be effective as sediment and pollution controlling mechanisms; riparian areas can be a source of organic matter and provide bank stabilization; and contribute habitat structure by way of large woody debris (LWD) (Williams *et al*. 2001). Functioning riparian zones can also be found along estuaries and beaches.

2.3.3 Beaches. This landscape class is defined or characterized as shorelines where the dominant process is littoral drift, which moves sediment by wave action. Beaches occur over large geographic regions of Puget Sound such as the east shore of the Sound from Edmonds south to Dupont, and the west side of Whidbey Island. Beaches are subject to greater wave and current energy than the other landscape classes largely because of the relatively greater distances over which wind and waves can travel (fetch). Several features can be embedded within beaches, including stream mouths, spits, bars, lagoons, rocky headlands, etc.

Drift cells are the process-based organizing unit over which (most) beaches operate. In general, the net drift of sediments along marine shorelines transports sediment from eroding areas to depositional areas along a mappable length of shoreline known as a drift cell. This fundamental unit of longshore sediment transport where waves and currents cause localized erosion, carry sediments for some distance down the beach in a predictable direction and deposit them when the wave energy is insufficient to keep the particles suspended. Sediment transport within shoreline drift cells determines the ultimate size, shape and configuration of soft sediment depositional features along the shoreline like beaches, spits, berms and mudflats. Larger sediment particles like gravel, cobble, boulders and large woody debris that wash from eroding bluffs travel the shortest distances because gravity exceeds the force of suspension. Woody debris that dislodges from the beach during high tides and smaller grain sizes like sand and silt, travel further along the drift cell or remain suspended to export offshore. These traveling sediments interact with freshwater outflows from streams and glacially carved curves of the shoreline and can create various landscape features. Figure 2-4 presents a graphic of a "typical" drift cell with erosional, transport and depositional sections.

This focus of littoral drift as the main process creating and affecting beaches leads to the identification of two types of features: 1) barrier beaches, which are generally depositional in nature, and 2) bluff-backed beaches, which are erosional regions.

The dominant habitat features in beach landscape classes include:

- Non-vegetated sand flats (gentle slope),
- Non-vegetated beach slopes of cobble, gravel, sand, and mixed substrates,
- Spits,
- Lagoons,
- Marshes,
- Fringing eelgrass (e.g., Hood Canal),
- Fringing kelp,
- Kelp beds – wave cut platform (e.g., Strait of Juan de Fuca),
- Rock – kelp (e.g., San Juan Islands).

- Backshore berms
- Vegetated bluffs[S6]

Many of these habitat features depend on a continual supply of sediment and wood moving through beach systems.

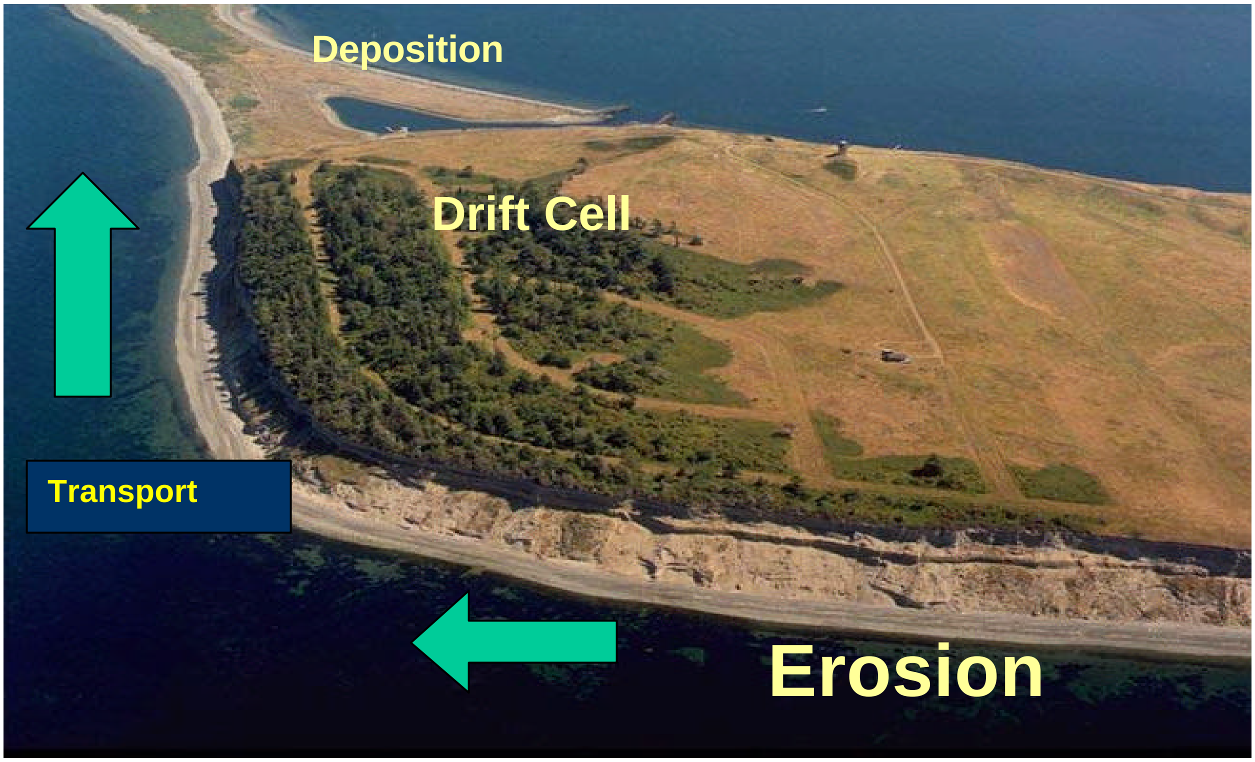


Figure 2-4. A "typical" drift cell in Puget Sound.

2.3.4 Marine Waters. The waters of Puget Sound include both neritic, or nearshore, and offshore waters. Using our definition of nearshore, we include neritic waters in the landscape classes discussed above. We have not, however, discussed the water column of these classes in the previous sections and so address them here.

The marine waters of each Puget Sound sub-basin connect either through other sub-basins or directly to the North Pacific Ocean (see Figure 2-3). The primary processes affecting the marine waters of Puget Sound include:

- circulation to deliver and mix water masses (e.g., from the Pacific ocean, other sub-basins, or river and stream discharges) with their characteristic temperature, salinity, nutrient load, and oxygen content;

- primary production of organic matter by phytoplankton and secondary production from resident pools or imported detritus; and

- trophic transfer of energy among organisms.

Defined (in part) by the interplay of these processes, habitat types within marine waters include the sea surface microlayer, surface water (photic zone), near-bottom waters, and soft or hard substrates of various types.

We have little information about the sea surface microlayer but expect that it is very important biologically (e.g., with concentrations of eggs and larvae of marine organism).

The controls on the processes of circulation and primary production include climate-ocean influences, the spatial arrangements of Puget Sound inlets and passages, and the delivery of nutrients. Estuarine circulation (as introduced earlier in Section 2) keeps surface waters somewhat distinct from deeper waters. Since surface waters receive sufficient sunlight to support photosynthesis, nutrients delivered to these waters (e.g., from freshwater discharges or mixing with deeper oceanic waters) can be consumed relatively quickly to fuel the growth of phytoplankton. Where the water column is fairly stable, phytoplankton can bloom to the extent that light and nutrient conditions allow. Primary production in many waters of Puget Sound is limited by the availability of nitrogen and these waters are susceptible to water quality impairments related to delivery of excess nutrients from pollution or oceanic events (PSAT 2002a).

Major ocean-climate effects on the Pacific Northwest and on Puget Sound marine water conditions relate to decadal time scale oscillations (PDO for Pacific decadal oscillation) between a phase of relatively warm and dry years and a phase of relatively cool and wet years. A shorter term El Nino-Southern Oscillation (ENSO) climate cycle interacts with the PDO and also affects the region with recurrent annual-scale shifts to El Nino (warm) or La Nina (cold) conditions in the Pacific Ocean. These combined PDO and ENSO climate phase shifts affect ocean temperature and salinity and this region's precipitation and air temperature. These factors in turn affect salinity, temperature, and primary productivity of Puget Sound marine waters by affecting the amount of solar radiation, rates of evaporation, patterns of runoff, and upwelling of ocean waters.

The (neritic) waters of the nearshore landscape classes (discussed above) receive particulate and dissolved nutrient inputs from land, rivers and streams, from fluxes out of sediment deposits, and from oceanic sources (e.g., through upwelling processes and estuarine circulation). Deeper marine waters are, in turn, influenced by ocean conditions and by mixing, especially at the surface, with neritic waters.

2.4 Major uncertainties & data gaps

Key uncertainties and data gaps related to the process that develop and maintain nearshore and marine ecosystems include:

- The role marine riparian zones play in contributing organic matter, nutrients, and food items across the terrestrial-nearshore interface;

- Historic distribution of habitats, and the processes that created and maintained them, the Puget Sound landscape;

- The functional state of fringing eelgrass beds and eelgrass meadows in various sub-basins of Puget Sound.

- Improved understanding and descriptions of the key ecosystem processes in bays (benthic-pelagic transfers of organic matter and nutrients, nutrient cycling moderated by filtering organisms and tidal circulation.

- Further evaluation of the linkages between climate variability, global climate change, and population dynamics.

3. SALMON IN THE NEARSHORE AND MARINE WATERS OF PUGET SOUND

A) Introduction.

In this chapter, we present the salmon portion of our salmon recovery conceptual model (Figure **xx**). This "salmon piece" presents our "hypotheses" about how salmon use the nearshore and offshore ecosystems of Puget Sound and how use of habitats in these ecosystems affects populations and ESUs. The conceptual model proposes that ecosystem processes (e.g., sediment movements and food web) as controlled by certain factors (e.g., geology and climate) define habitat conditions. Salmon then interact with and respond to this habitat. Recovery strategies and actions are then targeted primarily at the processes that create and maintain habitat.

Our discussion focuses primarily on salmon in nearshore ecosystems because: 1) we know more about nearshore use than we do offshore habitat use, and 2) the nearshore ecosystems of Puget Sound are where salmon and people most closely interact. Because the ultimate intent of this chapter is to help identify recovery strategies and actions at the subbasin scale, we also consider differences in use between subbasins when such distinctions can be made. We will highlight key uncertainties about salmon in the nearshore that will be considered further in the adaptive management plan (Chapter xx). We focus on chinook salmon and summer chum salmon because of their protected status under ESA. Bull trout are only briefly discussed in this chapter. The USFWS completed a separate recovery plan for bull trout that is available at the USFWS website http://pacific.fws.gov/bulltrout/jcs/index.html.

The chapter consists of the following major section:

1. An introduction to the listed populations of chinook and chum salmon within Puget Sound.
2. Effects of species, population, and life history strategy on use of nearshore habitats.
3. Nearshore habitat conditions.
4. A description of how chinook salmon and summer chum salmon use nearshore and offshore habitats.
5. Differences between sub-basins in salmon use of Puget Sound.
6. Response of individual salmon, populations, and ESUs to habitat in Puget Sound. .

b) The Puget Sound Chinook Salmon and Summer Chum Salmon ESUs

Chinook Salmon.

The Puget Sound chinook salmon ESU contains 22 independent populations (Table xx). The geographic distribution of the 22 chinook salmon populations is presented in Figure xx. These populations spawn primarily in the 13 largest watersheds entering Puget Sound including the large systems flowing west from the Cascades into Puget Sound. Chinook salmon are also occasionally reported to spawn in smaller tributaries in places like South Puget Sound.

Myers et al. (1998) reported chinook salmon within the Puget Sound ESU are primarily ocean type fish. Since first used by Gilbert (1913), the terms ocean type and its converse, stream type, have been widely applied to describe salmon species and populations (e.g., Healey 1991). We use the terms stream and ocean type consistent with Myers et al. (1998) to separate chinook salmon populations into two groups based upon certain characteristics exhibited by juveniles during their first year of life. These characteristics include how long they rear in freshwater, when they emigrate from freshwater and how long they spend in estuarine habitats. Populations are referred to as ocean type if most of the members of the population migrate to sea early in their first year of life after spending only a short period (or no time) rearing in freshwater. A shorter period of freshwater rearing is usually correlated with more extensive use of estuarine and oceanic habitats. In contrast, most members of stream type populations rear for at least a year in freshwater and so spend comparatively less time in estuarine and ocean habitats.

Most of the ocean-type chinook spawning in Puget Sound enter freshwater to spawn in late summer or fall (Healey 1991); these fall spawners are referred to 'fall run' chinook salmon. There are also spring and summer chinook salmon (entering freshwater in the spring and summer, respectively, but still spawning in the fall) spawning runs within the Puget Sound ESU. We refer the reader to the NOAA- Fisheries Chinook Salmon Status Review website (http://www.nwfsc.noaa.gov/publications/techmemos/tm35/index.htm) for a comprehensive discussion of juvenile chinook life history and ecology.

Table 2. Independent populations of Puget Sound ESU chinook salmon

1. Elwha	12. Skykomish
2. Dungeness	13. SF/Mainstem Stillaguamish
3. Dosewallips	14. Upper Sauk
4. Skokomish	15. Lower Sauk
5. Nisqually	16. Suiattle
6. Puyallup	17. NF Stillaguamish
7. White	18. Cascade
8. Green	19. Upper Skagit
9. Cedar	20. Lower Skagit
10. Snoqualmie	21. SF Nooksak
11. Lake Washington	22. NF/MF Nooksak

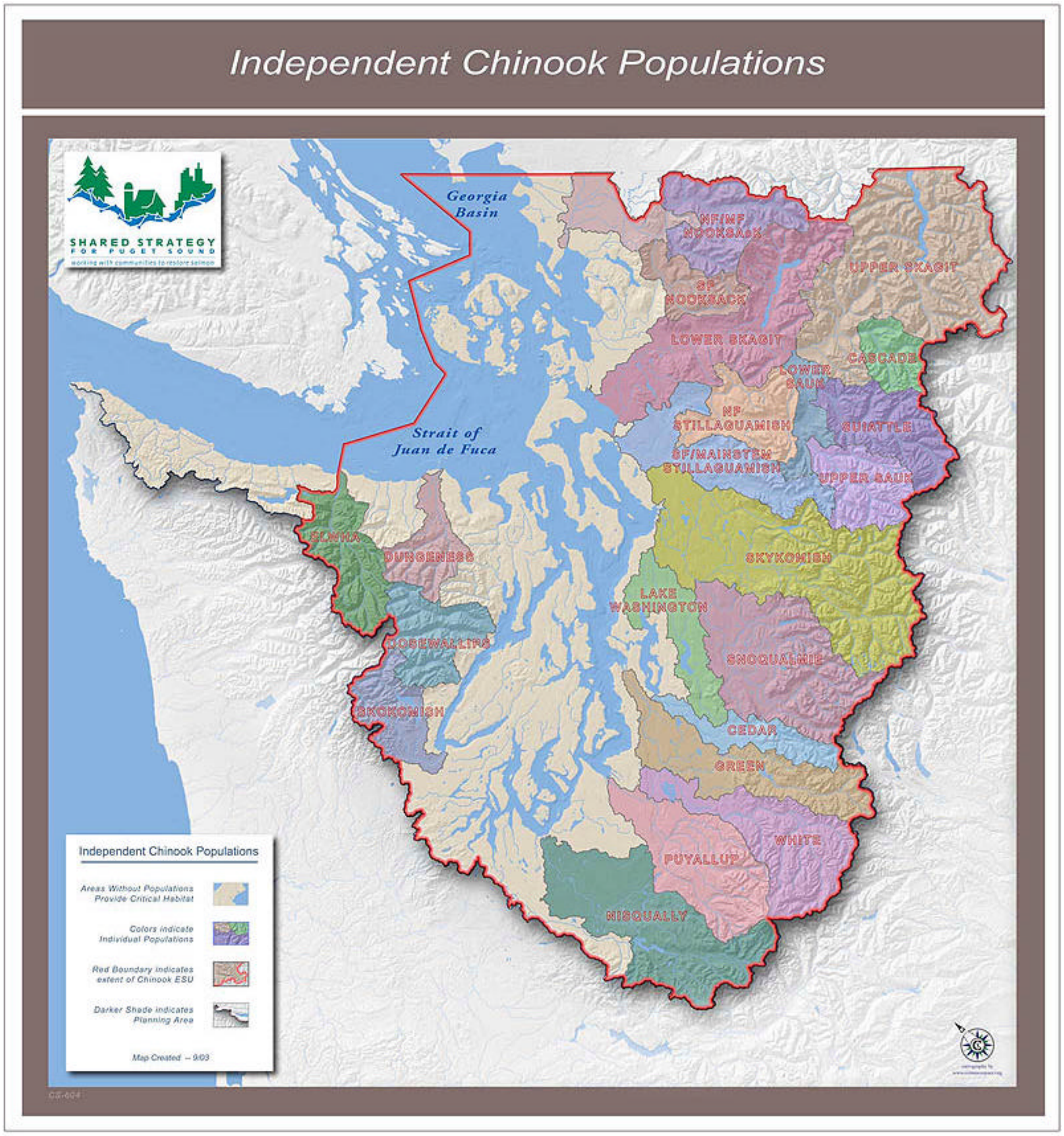


Figure 3. Independent populations of Puget Sound chinook salmon.

Summer Chum Salmon.

Within Puget Sound, chum salmon can be divided into three types of populations based upon spawning timing. Although there is some overlap between the three groups, summer-run chum salmon spawn primarily in August and September, normal or fall-run chum spawn from October to December and late-run chum spawn from January to March. Most of the chum salmon spawning in Puget Sound are part of fall-run populations. **Nine** populations of summer chum salmon found in the Hood Canal and eastern Strait of Juan de Fuca have been grouped into what is referred to as the Hood Canal summer chum ESU Table 3, Figure 5); these nine populations have been listed as threatened. There are other summer chum populations in Puget Sound (south Puget Sound) that have not been listed. We refer the reader to the NOAA- Fisheries Chum

Salmon Status Review website (http://www.nwfsc.noaa.gov/publications/techmemos/tm32/index.html) for a comprehensive discussion of chum salmon demographic, general life history and ecology.

This chapter addresses the eight independent populations collectively, not separately. The Hood Canal Coordinating Council (HCCC) is completing one chapter specifically addressing Hood Canal summer chum salmon within Hood Canal.

Table 3. Independent populations of Hood Canal summer chum salmon

1. Jimmy Comelately	5. Duckabush
2. Salmon/Snow	6. Hamma Hamma
3. Big and Little Quilcene	7. Lilliwaup
4. Dosewallips	8. Union

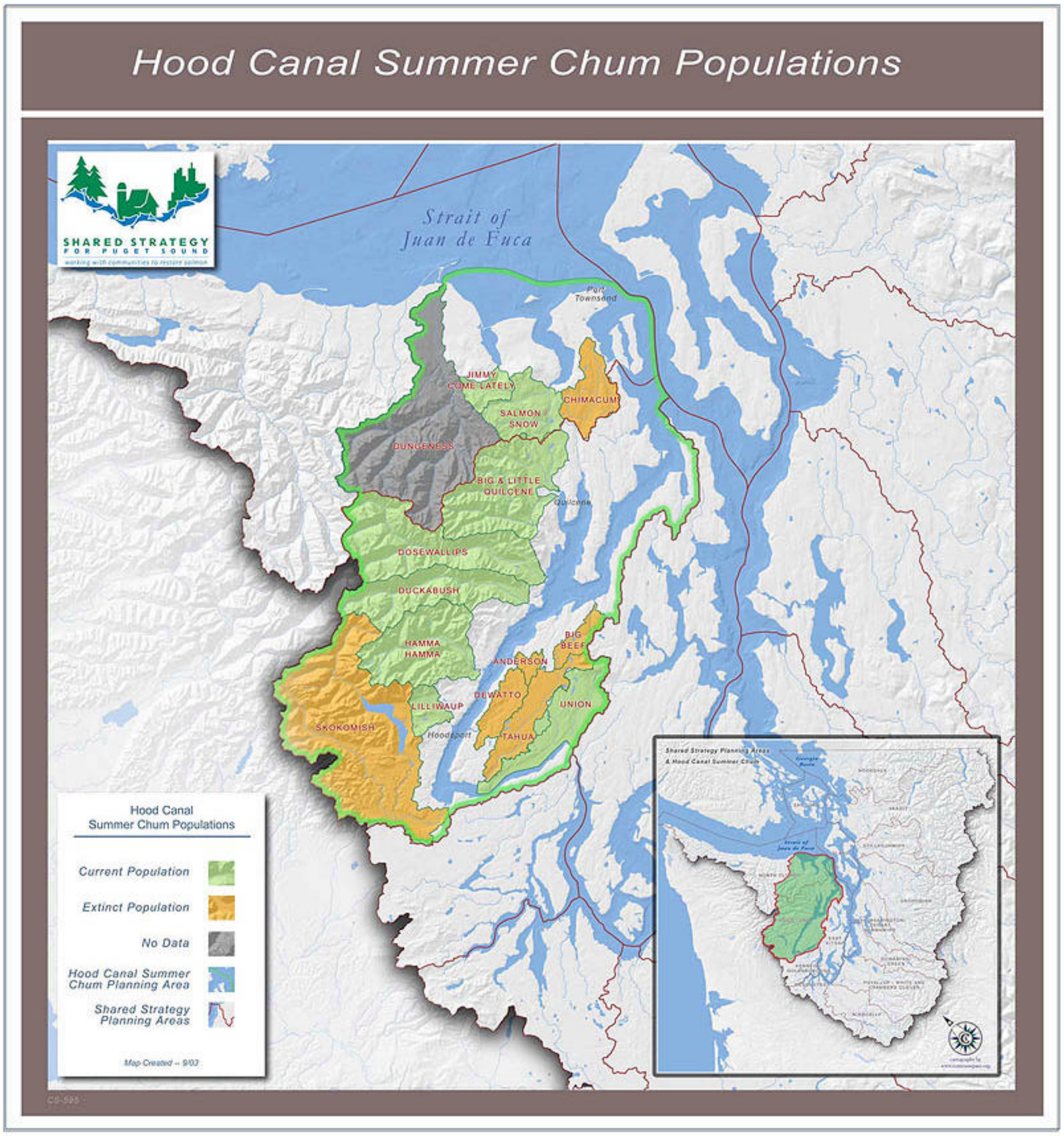


Figure 5. Independent populations of Hood Canal summer chum salmon.

c) Influence of Species, Population, and Life History Strategy on Nearshore Habitat Use.

It is clear from our 50+ years of research on salmon in nearshore systems throughout the Pacific Northwest that we cannot define a generic, one size fits all model of salmon use of the nearshore. Rather, we have found that differences in use of nearshore habitats occurs between species, between populations within a species, and between individuals within a population (e.g., Fresh et al. 1979; Levy and Northcote 1981; Levy and Northcote 1982; Healey 1982; Simenstad et al. 1982). These differences must be accounted for in planning, implementing, and monitoring protection and restoration strategies and actions for salmon in the nearshore. For example, actions that target specific habitats or landscapes to benefit one species or population may not be as beneficial to other species and populations.

Species-specific differences in use of nearshore habitats have long been appreciated. For example, the most estuarine dependent species in the juvenile stage is chinook salmon (Healey 1982) because they spend the most time rearing and feeding in these habitats; chum salmon are considered to be the second most dependent upon nearshore habitats (Healey 1982; Simenstad et al. 1982). Recently, we have begun to appreciate that population of origin and characteristics of individuals within a population can have a significant effect on use of nearshore habitats which can be important in the design, planning and implementation of recovery strategies and actions. Here, we briefly discuss the importance of population and sub-population differences in use of nearshore habitats.

Population

Populations are geographically discrete, self perpetuating, and semi isolated (in terms of genetic exchange) reproductive or breeding units of salmon; they are the fundamental unit around which much of modern salmon research and management is organized. McElhany et al. (2000) defines a population as "any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals with other populations." The extinction of one independent population would have negligible impact on the 100-year extinction risk of other independent populations (McElhany et al., 2000).

Populations form as a result of the specific spawning and rearing conditions (e.g., hydrological, estuary morphology, climate, ocean environment) experienced by different groups of salmon. Over long time scales, groups of salmon adapt to the specific habitat conditions that they encounter. These adaptations are expressed by each population in how they use the habitats available to them (e.g., residence time, body size, age at return, timing of life history events, etc). Therefore, each population within the chinook salmon and summer chums salmon ESUs do not use habitats (including nearshore habitats) in the same way. There is a wide body of literature that demonstrates that habitat use depends upon population of origin (Carl and Healey , Wilmot and Burger 1985, Burger et al. 1985, Beachum and Murray 1987, Burgner 1991, Healey 1991, Wood 1995, Woody et al. 2000, Hodgson and Quinn 2002, Miller and Sadro 2003, Ramstad et al. 2003).

The local adaptations by populations to spawning and rearing conditions results in genetic differences between populations, although some differences may result due to genetic drift (Stearns 1992). Within the Puget Sound ESU, the 22 populations of chinook salmon are genetically distinct from each other and from other populations outside the ESU. It is unknown whether genetic differences exist within the Hood Canal/Straits summer chum ESU.

Life History Strategy

Within any population, individuals vary in their approach to using spawning, rearing, and migration habitats in space and time. Differences within populations in use of nearshore habitats in such attributes as residence time, timing of arrival in the estuary, habitat usage, and size of arrival in the estuary has been demonstrated by a considerable number of studies (Reimers 1973, Carl and Healey 1984, Levings et al. 1986, Quinn and Unwin 1993, Bottom et al. 2001, Miller and Sadro 2003, D. Bottom, NOAA Fisheries, personal communication).

Each alternative approach to the spatial and temporal use of spawning, rearing, and migration habitats by individuals within a population can be defined as a life history strategy or life history trajectory (we use these terms to refer to the same thing) (Wissmar and Simenstad 1998). In the extreme, each member of a population is unique and has its own trajectory or life history strategy. However, individual trajectories can be bundled or aggregated into a more limited number of general trajectories based upon definable patterns in their spatial and temporal use of habitats (Reimers 1973, Carl and Healey 1984, E. Beamer, SSC, personal communication). In general, the abundance of members associated with each strategy will vary between and within populations in response to a wide range of factors operating over multiple scales of space and time. Under the prevailing environmental conditions, some strategies will produce more adult spawners than other strategies. As conditions change, the distribution or proportion of members associated with each life history strategy can then shift. Over short time scales (e.g., annually), the distribution of members associated with each strategy can vary in response to annual variability in flow, water temperature, biological interactions such as predation, and the occurrence of El Nino events. A sustained shift in conditions (e.g., a climate shift, anthropogenic influences) can potentially produce more significant shifts in the distribution of life history traits (Hilborn et al. 2003).

There is not a single or correct way to define life history strategies within a populaiton. In this chapter, we consider four alternative life history strategies for juvenile chinook salmon use of nearshore habitats based primarily upon research by Eric Beamer of the Skagit System Tribe. The primary attributes we use to distinguish these four life history strategies are with respect to how they use delta habitats, especially the size at estuarine entry and arrival time in the estuary. Size at entrance into the estuary can be used to classify life history strategy because there is a linkage between fish size and habitat use (Healey 1980, 1982; Levy and Northcote 1981, 1982; Simenstad et al. 1982; Levings et al. 1986; Miller and Sadro 2003). For example, time spent in the estuary generally decreases as the size of the fish entering the estuary increases. The time the fish arrive in the estuary also varies within a population in a reasonably predictable way (Carl and Healey 1984; Bottom et al. 2001). Because habitat conditions vary throughout the year, arrival timing represents a reasonable way to describe habitat use by salmon. Fish from any one population can arrive in the estuary during most months of the year (e.g., Rowse and Fresh) and there is a general relationship between arrival timing and fish size. Size at arrival in the estuary generally increases with Julian day of estuarine entry.

The following are the four life history strategies used in this chapter for chinook salmon populations:

1. **Fry migrants** – this life history type spends little time in freshwater after hatching (between 1-10 days) and migrates rapidly through its natal estuary/delta. These fish rear in and along nearshore regions, particularly in non-natal estuaries (what are referred to as pocket estuaries) that may be relatively remote from their natal river. Fish are small (<50mm) at the time of estuarine entry,
2. **Delta fry** - similar to pocket estuary fry except delta fry may remain in natal delta habitats to rear for extended periods of time. This life history type is also small sized (<50mm) when entering an estuary, and will leave their natal estuary at a size of about 70mm,
3. **Parr migrants** - remain in freshwater and rear for up to 6 months before migrating to the estuary. Fish from this life history type are larger in size when entering an estuary,
4. **Yearlings** - rear in freshwater for approximately one year before migrating to Puget Sound. Fish from this life history type spend a short time in an estuary.

A full accounting of these life history strategies associated with all chinook salmon populations in Puget Sound has not yet been conducted. However, our hypothesis is that all four life history strategies exist in each population, although the mix of these strategies undoubtedly varies between populations. We believe this is a plausible hypothesis for several reasons. First, where detailed studies of estuarine use by juvenile chinook salmon in Puget Sound have been conducted, data suggests that all four life history strategies exist in each natal estuary (Table **xx**). Second, research in systems outside the ESU indicates similar types of life history strategies can be defined based upon use of natal estuarine habitats (e.g., Carl and Healey 1984). For example, Fresh et al. (in press) proposed a similar hypothesis in the Columbia River that each population regardless of origin exhibited multiple life history approaches to use of the Columbia River Estuary. Emerging data from ongoing research in the Columbia River estuary has supported this hypothesis (xxxxxxxxxx).

Alterations of delta habitats has probably affected the expression of the delta fry life history strategy in some systems; the habitat simply is not there for the fish to use. Historic changes in natal watersheds may have completely altered the mix of life history strategies including creating strategies that did not historically exist. In some systems where fry have been found, separating them into the delta and migrant types is challenging unless sampling can be extended outside natal systems to find the migrant fry type. Otolith analyses could help make such distinctions as well. In watersheds that have multiple populations (e.g., the Snohomish River), we have been unable to determine population specific life history strategies; we are only able to identify the existence of life history strategies at a watershed scale.

In general, once juvenile chinook salmon exit natal deltas, we are unable to distinguish the different life history strategies and so we do not know if differences in habitat use persist. One exception is use of a rare habitat type in nearshore areas by migrant fry. As a result, once the chinook salmon exit natal deltas, we will aggregate the four life history strategies into a single generic chinook salmon model. This is not to say that there are not life history strategies in

Puget Sound. In fact, some chinook salmon within a population appear to reside in Puget Sound for extended periods while most members of a population migrate to the ocean. These resident salmon are often referred to as blackmouth. We do not know how juvenile life history in the delta may be related to extended residency in Puget Sound- e.g., do residents come from certain populations or certain delta life history strategies. Where appropriate, we will consider other life history strategies during residence in Puget Sound.

Although our treatment of life history strategy is based upon use of Puget Sound, there may be other expressions of life history diversity by chinook salmon populations. For example, spawning location (headwater versus mainstem spawning) within a watershed may be an important element of life history diversity. Similarly, spawning by some chinook salmon in small, independent tributaries may represent an element of diversity.

Although summer chum may have some consistent life history strategies within their populations, we have yet to identify this type of diversity within the Hood Canal ESU. As a result, we do not distinguish alternate life history approaches in our consideration of summer chum use of nearshore habitats in this chapter.

d) Nearshore Habitats

The nearshore ecosystems of Puget Sound consist of a mix of habitats that juvenile salmon can potentially occupy. Habitat is the physical, biological, and chemical characteristics of a specific unit of the environment occupied by a specific plant or animal (in this case, salmon). Thus, habitat is unique to specific organisms and encompasses all the physiochemical and biological requirements of that organism within a spatial unit.

Physical, Chemical, and Biological Salmon Habitat

A diverse array of attributes can be defined to define physical, biological, and chemical habitat of salmon in nearshore ecosystems. Physical habitat represents the structural features of the habitat used by salmon. Within a delta, physical habitat includes such attributes as location of a marsh channel, length of the channel, average depth, connectivity to main distributary channel, depth profile, and so on. Within a shoreline environment, physical habitat includes substrate composition, beach gradient, exposure to wave energy, characteristics of adjoining riparian vegetation, and composition of habitat along the beach. The most obvious chemical habitat attributes are temperature, salinity and dissolved oxygen. These three parameters have a significant affect on the functions of that habitat. For example, water temperature affects metabolic rates and hence food acquisition and growth. Salinity regimes within a delta can determine the physiological changes fish undergo as they undergo smoltification.

Biological habitat includes all the plant and animal species and communities that salmon interact with. Salmon can interact both directly and indirectly with biota. For example, direct interactions are those where salmon prey on a species, compete with a species for resources, or are preyed on by a species. Indirect interactions with biota include those occurring with attached vegetation such as eelgrass and marsh plants.

These plants can produce prey or provide refuge from predation but they are not directly used (eg eaten) by salmon. Biological habitat components can vary according to their location in the nearshore, time of year, size of the salmon, species of salmon being considered, and so on.

The interaction of salmon with their predators and prey can be organized into food webs. These food webs illustrate the interrelationships of salmon with other members of the nearshore ecosystems and clearly show that factors affecting the production of particular species can significantly affect salmon performance. For example, Figure xx shows a portion of a non-deltaic nearshore food web that includes salmon. At the life stage represented in this Figure, salmon are larger and exploit herring and other baitfishes as food. Thus, the ecosystems processes that affect production of herring and these baitfishes (e.g., habitat used by herring, sources of organic matter used by prey of herring, other predators of herring, and so on) cann have a direct affect on growth rates and ultimately survival of salmon. Similarly, salmon of this size in this habitat are preyed on by marine mammals and birds. Factors affecting population sizes of these species can directly affect salmon survival.

Within both delta and shoreline habitats, chironomids and other insects are important food items. These insects can come from either aquatic or terrestrial habitats depending upon the type of insect they are. For example, some chironomids originate from within marshes. Their productivity then depends upon a variety of habitat factors that affect chironomids such as their food supply and the organic matter important to the production of insect food and physical habitat that the insect occupy (e.g., plant species).

Salmon Habitat: Effect of Scale

The biophysical and chemical attributes of habitat can be measured at multiple scales of space and time. These range from the “microscopic” (mm to cm) to the regional (hundreds of square km). Traditionally, juvenile salmon habitat in nearshore ecosystems has been considered primarily at a site or patch scale. Examples of patch or site scale habitat attributes in a tidal marsh include area of the marsh, volume of the marsh, vegetation type and density, salinity and temperature patterns, and channel depth at the mouth of blind tidal channels. However, it has become increasingly apparent in recent years that simply relying on site scale habitat attributes to study, manage, protect and restore salmonid populations can lead to approaches that are ineffectual. Instead, as Simenstad (2000), Simenstad et al. (2000) and others have proposed, we believe that a landscape view of habitat is also essential. Landscape context of habitat refers to the spatial arrangement of habitat, including its size and shape; location of the habitat within the estuary; the composition of surrounding habitat; and connectivity with other habitats (Turner 1989). A landscape view of salmon habitat integrates specific sites and habitat types with all other elements of the landscape, including the arrangement, size, shape, location, connectivity to other habitats, and accessibility of that habitat to resources. In short, what this means is that the function of any unit of habitat depends upon the context of that habitat within the “bigger picture.”

A landscape approach to salmon habitat is warranted for several reasons. First, the physiological and ecological requirements of the fish are rapidly changing as they move through the nearshore implying a need to change habitats (Simenstad et al. 2000). Second, during their residence in the nearshore, salmon juveniles are mobile and migratory and so are not affiliated with a particular site for very long. In essence, juvenile salmon are always going someplace and have always come from someplace. Third, nearshore habitats are dynamic in nature; depth, temperature, salinity, turbidity levels, and many other attributes continuously and rapidly change of multiple spatial and temporal scales. Many habitats such as shallow water, blind channels are not consistently accessible. The ebb and flood of the tide in delta marshes means that fish are being redistributed every tidal cycle because of changes in depth. Finally, many of the process that create and maintain habitat operate at large spatial scales (see following section).

Principles and concepts of landscape ecosystem are relatively recent and can be found in such sources as Turner (1989); they are being applied in restoration of salmonid habitats in freshwater (Roni et al. 2002). One example of the application of landscape metrics in nearshore systems is from the Chehalis River where Hood (2002) showed how differences in landscape features (e.g., perimeter and surface area) of a restored and natural channel affected their function. In addition, Simenstad (2000) discussed juvenile salmon integration at large landscape scales in his assessment of the Commencement Bay aquatic ecosystem. He described three landscape elements important to salmon and salmon recovery in an estuarine landscape: 1) *patches* ("non-linear surface areas, relatively homogeneous internally…that differ in appearance from surrounding matrix in which they are imbedded," characterized by several variables and determined by a combination of several processes; can be referred to as habitats), 2) *matrix* ("surrounding area that has a different composition or structure from embedded patches; the most extensive, connected element in the landscape") and 3) *corridors* ("narrow strip of land (or water) that differs from the matrix on either side;…can also be considered a narrow and often long patch that provides a connection between two or more similar patches").

As our understanding of landscape features and habitat functions for salmon increases in nearshore areas, the recommendations of Simenstad et al. (2000) provide useful initial guidance for incorporating landscape concepts in the recovery of nearshore ecosystems:

1. Use natural landscape templates as templates to increase our understanding of landscape attributes. Use templates that are specific to the estuary and local region to guide restoration,
2. Emphasize corridors and linkages (i.e., connectivity) between habitats at all scales (e.g., between and within complexes of habitats such as in marsh habitats,
3. Incorporate landscape elements that maintains a natural diversity of sources of organic material, and
4. Promote landscape structure that accommodates fish responses to climate and natural disturbance regimes

Attributes of Salmon Habitat: Opportunity and Capacity

Simenstad (2000) and Simenstad and Cordell (2000) proposed that salmon habitat attributes at any scale could be considered from two primary perspectives. First, there are attributes of habitat that relate to the *quality* or *capacity* refers to habitat attributes that encourages production for juvenile salmon via things such as feeding and growth and reduced mortality. Examples include prey production and availability and maintenance of prey communities. The second category is *opportunity*, which refers to the juvenile salmon's ability to "access and benefit from the habitat's capacity." Examples include tidal elevation, important during tidal flooding, available geomorphic features "that often dictate both the extent of fish access into habitats and the interface along which they feed," refugia from predation via physical features, and "proximity to deepwater habitats."

The measure of the usefulness or value of any unit of habitat to salmon is a product of the combined effects of the capacity of the habitat to support salmon and the opportunity the fish have to use that habitat. There are a number of physiological and behavioral measures of how well that habitat functions for salmon including growth rates, residence time, migration rate, distributional patterns, relative abundance, physiological responses, and morphological changes.

The ultimate measure of the value of habitat to salmon is how well fish occupation of that habitat promotes survival. Measuring survival of any cohort for any species during nearshore residence is difficult so has been rarely accomplished. Bax (1983) and Parker (1968) provide estimates of early marine morality of chum and pink juvenile respectively. Estimates between the two studies vary by about one order of magnitude and suggest that mortality is high and variable. On the Columbia River, Ryan et al. (2003) found that predation rates on PIT tagged smolts in the Columbia River by nesting birds in the estuary varied by species and size. For example, loss of PIT tagged steelhead was about 18% while about 2% of smaller chinook were lost. Given that these are only PIT tagged fish morality estimates, levels would be higher if the untagged portion of the population was included. Recent advances in technology such as PIT tags and small sonic transmitters may make morality estimates more logistically feasible.

The ability of any unit of habitat to promote or affect survival reflects the net cumulative ability of all the attributes associated with that habitat (those related to both capacity and opportunity) to support four main functions: 1) foraging and growth, 2) avoidance of predators, 3) the physiological transition from freshwater to saltwater, and 4) the ability of the fish to migrate to ocean feeding habitats (Simenstad et al. 1982; Simenstad and Cordell 2000). Although we discuss these four functions in greater detail below, they are clearly interrelated. For example, growth and survival are interrelated as growth rate reflects how rapidly the fish can "outgrow" portions of their predator population. Similarly, fish that "struggle" to make the transition to saltwater may be less able to avoid predators than those that make a smooth transition.

Feeding. Juvenile salmon feed and grow in all habitats that they occupy. Not surprisingly, the types of prey available to the juvenile chinook salmon will vary widely across the habitats occupied by salmon. For example, pelagic copepods are an abundant prey along shorelines but relatively rare within deltas. There is not a correct prey type for juvenile chinook salmon. Instead, fish appear to feed somewhat opportunistically as a function of habitat occupied, time of year, and fish size. It is not known if fish of different life history strategies occupying the same habitat have differences in diet due to their life history strategy. Often, there is considerable individual variation in diet for fish of similar size captured in the same habitat type at the same time of year.

In general, juvenile chinook salmon eat a diverse array of prey items that originate from terrestrial, aquatic, benthic and water column sources. For several of these prey types, the food web producing this prey is fueled by organic matter originating from within the nearshore. Such nearshore food webs based upon detritus appear to be especially important to the smaller size classes of juvenile chinook which eat these types of prey. Several general patterns emerge from a comprehensive analysis of juvenile chinook salmon diets. First, as fish size increase, prey size increases as well (Simenstad et al. 1982; MacDonald et al. 1987). Second, in all landscape classes, insects, especially chironomids are important prey (Simenstad et al. 1982; Shreffler et al. 1992; Miller and Simenstad 1997; Gray et al. 2002, MacDonald et al. 1987; Healey 1991).

There are relatively few estimates of growth rates of juvenile chinook salmon and most of what is known comes from estuary/delta habitats. Considerable variability exists both within and between deltas but growth rates during nearshore residence appear to be some of the highest exhibited by the fish during their life histories. For example, growth rates in different systems ranged from a high of 3.0 mm/d in the Sixes River to 0.27 mm/d in another study of the Sixes River (see Miller and Simenstad 1997, Table 2). Within any one system, growth can vary considerably as illustrated by the threefold difference Reimers (1973) found for juvenile chinook in the Sixes River. Again, we do not know what factors account for these differences.

Studies in the Skagit River delta suggest that food can be limiting in nearshore areas under some conditions. Beamer has found that the carrying capacity of estuarine habitats in this system are often exceeded under current conditions (E. Beamer, SSC, personal communication to K. Fresh, NOAA-Fisheries). Beamer observed that there was a relationship between the number of fry migrants entering the estuary and the density of fry in tidal channels. While this relationship suggests a carrying capacity, it is not clear what happens to the fish as a result- e.g., do they leave and move to another habitat such as shoreline areas, is their growth rate affected, is survival affected. Given that the Skagit Delta arguably is the best estuarine habitat in Puget Sound and there have been extensive losses of habitat in other deltas, it is not unreasonable to assume delta habitats in other systems are now often at or exceeding their carrying capacities for chinook fry as well.

Refuge From Predation. During their life history, salmon are subjected to predation from a wide variety of fish, birds, and mammals (Fresh 1997). Simenstad et al. (1982) suggested the nearshore could provide a refuge from some of this predation. There are a number of mechanisms by which this could occur. First, estuary/delta habitats are often turbid as a result of sediment laden river water and resuspension tidally of fine materials from delta habitats. Several studies have found that some turbidity can reduce visibility of salmon juveniles to predators while high enough levels of turbidity can limit the ability of juvenile salmon to forage for food (Gregory). Two, the shallow water habitats associated with many shoreline areas, pocket estuaries, and deltas can provide a refuge from some larger piscivores such as cutthroat trout and large sculpin. Third, high growth rates can provide a refuge from predators by allowing the juvenile salmon to outgrow their predators.

Physiological transition. Juvenile salmon undergo a physiological transformation during their transition from freshwater adapted to saltwater adapted animal. Part of this transformation occurs in the nearshore. Despite a large amount of research on smoltification (e.g., Wedemeyer et al. 1980), we have a limited understanding of the physiological changes juvenile chinook of any size are undergoing as they pass through estuaries and how habitat affects physiological condition. It is possible that habitat selection for at least part of life in nearshore habitats is dictated by physiological needs so that water chemistry, particularly salinity, may play a more critical role in defining fish behavior in estuaries than other habitat attributes. Presumably, because the salinity patterns are most diverse and different in estuary/delta habitats, it seems reasonable to hypothesis these habitats are most critical for the physiological transition of the fish. Chinook salmon fry can tolerate some salinity but most fry are found in lower salinity habitats such as marsh channels (Grette *et al*. 2000). Some chinook fry may remain in lower salinity or freshwater regions for extended periods after arriving at an estuary (Grette *et al*. 2000). In addition, estuaries may benefit juvenile salmonids such as chinook and chum salmon because these regions can offer a gradual transition from a freshwater environment to a saltwater environment (Aitken 1998).

Migratory pathway. Salmon are a migratory animal over their entire life history so it is important to recognize that salmon are always going someplace and coming from someplace else. Thus, all habitat that is part of the life history of salmon is a part of the pathway they must follow. To survive, salmon depend upon being able to move between habitats. The nearshore represents the part of the salmon pathway from freshwater spawning and rearing areas to oceanic feeding grounds. Thus, the connectivity and integrity of nearshore habitats as a whole will have a profound affect upon the ability of salmon to make this journey to ocean feeding habitats. Simenstad (2000) suggested that salmon recovery should emphasize corridors and linkages (i.e., connectivity) between habitats at all scales (e.g., between and within complexes of habitats such as in marsh habitats). Certain landscapes and habitats will likely be more important to different species and life history strategies within species. Therefore, because multiple species and life history strategies are occupying this pathway simultaneously, a diversity of habitats and the connectivity of this habitat seems especially important to its functions as a migratory corridor.

e) Use of Nearshore Habitats by Salmon

In the following section, we present general descriptions of how salmon use nearshore habitats. Our objective here is to develop some general rules or principles of habitat use that can be applied in developing salmon recovery strategies and actions. In a subsequent section, we identify some important. We discuss summer chum salmon and chinook salmon separately. Because we cannot yet differentiate different life history strategies for summer chum salmon, we present a generic summer chum salmon model, relying primarily upon information provided in Salo (1991) and the summer chum conservation plan (XXXX). For chinook salmon, we discuss delta habitat use based upon the four life history strategies defined previously. Once fish exit natal deltas, however, we aggregate these four life history strategies into a general chinook salmon model and only consider different life history strategies when consistent with available information. .

In order to discuss use of nearshore habitats, a method of describing nearshore habitats is needed that is consistent with information on habitat use by salmon and the landscape classes being used to analyze each sub-basin. Although a number of habitat classifications are available, these are too detailed compared to our knowledge of salmon use. Therefore, to describe use of Puget Sound ecosystems by salmon we will consider the following habitat types:

1. Natal estuary- Fluvial processes tend to dominate, such as delivering sediments. For chinook salmon, this includes the larger systems throughout Puget Sound. Summer chum natal estuaries are smaller and limited to the Hood Canal and Straits.
2. Other estuary- Fluvial processes tend to dominate, such as delivering sediments.
3. Bays/Shallow Water, Low Velocities- Tidal processes are especially important to sediment delivery and movement. Pocket estuaries are defined as types of bays (other names used include barrier estuaries and barrier lagoons) that are distinguished by being geomorphically constricted at the mouth by a barrier. The amount of freshwater influence can vary.
4. Beaches- Wave dominated systems.
5. Water column associated with the shore- Water column extending from a depth of about 5m to 20 m (lower limit of the photic zone).
6. Puget Sound offshore- Surface to bottom from a depth of 20m.

Chinook Salmon.

One of the major variables affecting use of nearshore habitats is when the fish initially enter the natal delta. Within the Puget Sound chinook salmon ESU, spawning occurs in the fall. Based upon arrival of fish in the estuary in December (E. Beamer, personal communication), emergence begins as early as late December and continues through April. The pattern of emergence (e.g., timing) depends primarily upon population, where spawning occurred (e.g., head water stream versus a lower mainstem stream), when the eggs were deposited, oxygen levels, and water temperature. Water temperature has a critical influence on variability in emergence timing with warmer water temperatures speeding up development and resulting in earlier emergence timing.

Emerging fry embark on one of three major pathways. First, they can begin migrating downstream soon after emergence and enter the estuary with little or no rearing. Second, emerging fry can rear for less than year in freshwater for migrating downstream to enter the delta; these are parr migrants. Third, they can rear for over a year and emigrate as yearlings. While we can distinguish use of natal estuaries by different life history strategies, our ability to discriminate use in Puget Sound is limited. As a result, we consider first use of natal estuary habitat by each strategy and then aggregate them to discuss habitat use in Puget Sound. Each of these strategies is considered below.

Fry. Fry begin entering natal deltas in at least mid-Demember (Beamer personal communication) and continue until at least April. Healey (1980) suggested that abundance of fry migrants peaked in April and May in the estuary and that the fry disappeared from the delta prior to the arrival of fingerling migrants. The peak of fry in the Snohomish River delta also occurred in approximately April and May (M. Rowse, NWFSC, personal communication) while Levings et al. (1986) reported a similar peak in abundance in the estuarine habitats of the Campbell River estuary. Although size at estuarine entry can be variable, fry are less than 50mm when they enter the estuary (Levy and Northcote 1982; Beamer et al. 1993; M. Rowse NWFSC, personal communication; E. Beamer SST personal communication).

As the chinook salmon fry enter their natal estuary, they can either quickly pass through their natal estuary into Puget Sound or they can remain in their natal estuary to rear for extended periods before exiting. The fry that pass through natal deltas without rearing are the migrant fry strategy. At present, we lack knowledge of how they disperse throughout the nearshore after exiting the estuary. We hypothesize physical processes associated with river and receiving environment primarily determine dispersal. One possible mechanism that might control dispersion is patterns of freshwater outflow and the oceanography of the area adjacent to the delta. The migrant fry may entrain in the brackish water of the natal system plume and move with this plume.

Dispersal requires further study and is important because it will help define which shoreline areas are critical to this life history strategy. Until we conduct these studies on dispersal, we assume that shoreline areas adjacent to natal deltas are especially important to this life history strategy. One reason why adjacent areas may be most important are because of the limited swimming ability of these small fish. Here, we define *adjacent* as being within 5 miles of the edge of delta, although we recognize that physical processes are what likely regulate dispersal of fry.

Recent studies in Whidbey Basin suggest that a major distinguishing feature of habitat use by migrant fry is their use of pocket estuaries (Beamer et al.). Fry apparently find and occupy these shoreline features of Puget Sound. It is possible that these non-natal "estuaries" function similarly to the functions of the main delta for delta fry. We hypothesize that if a non-natal pocket estuary contains freshwater input early in the year, this could serve as a region of continuing osmoregulation after fry migrants locate pocket estuaries. We speculate that this could have occurred because impacts to major deltas have caused these pocket estuaries to be more important then they were historically.

We do not fully understand use of pocket estuaries and how factors such as how distance from natal estuary, size, amount of freshwater input, vegetation patterns and so on affect use within and between these systems. For example, tidal influence within a pocket estuary may be important in defining the small scale habitat use patterns for salmon. Flood tides extend into/near riparian areas allowing the fry migrants to access areas higher in an elevated band along the shoreline that may mean access to more terrestrial insects and detritus materials for feeding. We also do not know if non-natal estuaries have similar functions but we believe it is reasonable to hypothesize that these systems provide similar support to migrant fry. Clearly, such a hypothesis needs further study. Consistent with our hypothesis about dispersal, we hypothesize that the closest pocket estuaries (ie within 5 miles) are especially important for this life history strategy because they are directly occupied by the fish. More distant pocket estuaries may have other functions such as export of organic matter and food which should be considered in their management.

While some fry pass quickly through the estuary, others remain to rear in natal estuaries to rear- the delta fry trajectory. Although we have much to learn about use of natal estuaries by chinook salmon, it is very clear that natal estuarine habitats are a key part of the ecology of this life history strategy. Loss of natal estuary habitat has undoubtedly affected production of this particular life history strategy. Important information needs include data on movements within and between habitat zones, how, flow regimens, tidal cycles and estuarine geomorphology affect distributional patterns, and effects of habitat quality, quantity, and spatial distribution of habitat varies.

As chinook fry enter the estuary, they are probably distributed and moved through each system by a combination of tidal and fluvial processes. It is likely that these dispersal patterns are unique to each estuary and depend upon the fundamental form and geomorphology of each system. Understanding dispersal patterns are important since this will affect which parts of the estuary the fish can find and then access.

We know from studies in a broad array of estuarine systems that small (1 or 2 order), blind tidal channels (channels that end) or other non-main channel habitats (e.g., sloughs) distributed throughout the estuary are critical habitats for rearing delta fry (Healey 1980; Congleton et al. 1981; Levy and Northcote 1982; Levings et al. 1986; MacDonald et al. 1987; Shreffler et al. 1990; Miller and Simenstad 1997; M. Rowse NWFSC, personal communication; E. Beamer, SST; personal communication; D. Bottom, NWFSC, personal communication). Optimal habitat conditions for juvenile salmon in estuarine and delta areas appear to be a low gradient and shallow water system containing fine-grained substrates (silts and mud), low salinity, wetland vegetation species, and low wave energy (Shreffler and Thom 1993; Aitken 1998; Simenstad 2000). Use of off channel areas can only at higher tides because at lower tides, the channels are often dry. As the tide ebbs and water drains from these marsh channels, fish must move into habitats and areas that are wetted (Mason 1974; Levings et al. 1986). While such cyclic redistributions of fish must occur in all estuaries, what constitutes suitable low tide refuge is unknown. Presumably fish access larger sloughs, distributary, and main channels, or temporarily leave the delta and move into Puget Sound before migrating back into the vegetated marshes on the next flooding tide. The availability of suitable refuge habitats and their connectivity to marsh channels may be critical features of estuarine habitats and as important to the fish as the channels themselves and therefore warrants further research.

As discussed previously, growth rates can be high in natal estuaries but that considerable variability exits in growth rates from individual estuaries ( ). As we also noted, food items used by juvenile chinook are diverse and depend upon fish size and habitat type as well as time of year. Within estuaries, insects that are derived from marsh habitats or possibly transported from upstream and terrestrial locations appear to be especially important diet components ( ). In addition, small crustaceans such as amphipods can be important prey types, especially in lower portions of the deltas ( ). In addition to physicochemical processes, Simenstad (2000) discusses the importance of secondary production processes in supporting juvenile salmon across the landscape, with the primary goal of reaching the largest physical size before entering the ocean environment. This, combined with predation issues, “can be a strong determinant to successful return to spawning” (Simenstad 2000). Some of the processes benefiting juvenile salmon and discussed by Simenstad (2000) include 1) primary production (organic matter availability and physical refuge via vegetation, temporal contributions of detritus, and nutrient cycling); 2) retention and decomposition of organic matter (variability in trapping rates by vegetation species, residence time and decomposition of detritus); 3) juvenile salmon growth and survival (salinity transition zones to accommodate sufficient physiological adaptation, low energy habitats for weak individuals, refuge from fish and birds via habitat structure and turbidity, locations of preferred prey concentrations, and prey trapping via certain hydrological action); and 4) trophic relay linkages such as prey export from habitats and subsequent uptake by organisms in the food chain.

Residence times of fish in individual tidal channel complexes varies both within and between systems (Congleton et al. 1981; Levy and Northcote 1982; Shreffler et al. 1990; Miller and Simenstad 1997). Estimates of residence times in estuaries range from 25 to 90 days (Reimers 1973; Healey 1980; Levings et al. 1986). Healey (1980) estimated that residence time of individual fish in the Naniamo River estuary was about 25 days while Levings et al. (1986) estimated that residence times in the Campbell River estuary were 40-60 days. It is interesting that some fish repeatedly use the same channel despite tidal actions (Levy and Northcote 1982). It is unclear what attributes account for variability in residence times within and between different system.

Parr Migrants. During the late spring, juvenile chinook of the fingerling or parr migrant strategy eventually migrate downstream to the estuary after rearing and growing in freshwater habitat (fingerlings are also sometimes used to denote parr- Bottom et al. 2001). In the estuary, these migrant parr mix with the delta fry where they are indistinguishable except some internal characteristics such as chemical signatures on the otoliths. In addition to these natal fry, there may be non-natal fish that migrate into deltas and mix with natal fish. We do not know if use of delta habitats by parr and fry and by natal and non-natal fish varies. We assume without further information that chinook juveniles of a similar size are present in the estuary at the same time use the same habitats, have similar growth rates, diet and so on, regardless of their origin.

Arrival of parr migrants in the delta begins in late May. Catch data from throughout Puget Sound suggests the peak of fingerling migrant abundance in the estuary is May to mid July although small numbers of parr can be found migrating downstream throughout the summer (D. Seiler, WDFW personal communication). Parr migrants migrate downstream towards deltas as they are smolting (D. Seiler, WDFW personal communication).

Yearling Migrants. Some fish within each Puget Sound population of chinook salmon appear to rear for a year in freshwater before leaving. The proportion of yearlings varies within and between populations. Because of their extended residence in freshwater, they enter natal estuaries at a large size. Available evidence suggests that estuaries function primarily as a migration route to Puget Sound as yearlings are only in estuaries for a short period ( ). We have a poor understanding of habitat use but in the Snohomish, chinook yearlings were observed in all habitat types (Fresh, personal commuciation).

Use of Puget Sound Nearshore Habitats. Eventually, all fry that have been rearing in estuarine/delta habitats leave natal estuaries along with migrating parr and yearlings and move into shoreline areas where they probably mingle with migrant fry. Because of similar size, it is impossible without analyzing otoliths or scales to distinguish these life history strategies in the Puget Sound. We have a limited understanding of what causes juvenile chinook in delta habitats to eventually leave. Two hypotheses, that are not mutually exclusive, seem plausible. One hypothesis is that residence time and emigration of fry from estuaries is size dependent (Healey 1982) with residence time inversely related to fish size at estuarine entry. There is some speculation that the transition of juvenile chinook into Puget Sound occurs at a specific size (Duffy 2003). For example, Healey (1980) concluded that fry left the estuary at a size of about 70 mm since he never saw smaller fry than this size in adjacent marine waters. This would suggest that larger fish entering the estuary do not stay as long as the early migrating fry and helps explain why parr and yearlings pass relatively quickly through natal estuaries.

Another hypothesis is that emigration from estuaries is dependent upon delta water temperatures. As flows drop, air temperatures rise, and bottom sediments warm, water temperatures in delta habitats will eventually exceed 17 C, a level that is considered stressful to fish. In the Snohomish Delta in 2003, water temperatures >17 C occurred from July to September (M. Rowse, NWFSC, personal communication); water temperatures > 21 C (near lethal to salmon) were consistently found in blind channel habitats. These warm water temperatures may push fish out of channel habitats and into either deeper refuge areas in larger channels or out of deltas into shoreline areas.

Although we have been studying shoreline use of Puget Sound since the 1970's, our understanding of habitat use in this environment is limited. This lack of understanding is due to a variety of factors including an inability to determine population of origin, an inability separate life history strategies, separate natal and non-natal fish, and an inability to separate hatchery and wild fish. Further, we have yet to systematically evaluate use of shoreline areas based upon habitat characteristics (e.g., how fish respond to variation in substrate or oceanographic features), although emerging data from the Whidbey Basin will help fill this data gap in the near future.

Chinook salmon abundance in shoreline habitats of Puget Sound typically peaks in June and July (Stober and Salo 1973; Fresh et al. 1979), although some juvenile chinook can be present in shoreline habitats as late as October (Stober and Salo 1973; Fresh 1979; Fresh et al. in prep, C. Rice, NWFSC, unpublished data). As we noted previously, emerging data from coded wire tag recoveries of hatchery fish suggests that chinook juveniles move about considerably within Puget Sound and do not simply leave Puget Sound in a directed fashion. We assume that wild chinook from any population are also dispersing widely such that within any area of Puget sound, a mixture of fish from multiple populations can occur. We do not know if use of exposed and protected shoreline areas fundamentally differs for each life history strategy and for fish from different origins within an area. Studies of juvenile salmon use of Puget Sound suggest that shoreline habitats by juvenile salmon are dependent upon size of the fish (Schreiner 1977; Duffy 2003). Therefore, we assume without further information that chinook juveniles of a similar size in the same place at the same time use the habitat in the same way, have similar growth rates, diet and so on regardless of their origin.

Available literature suggests that there are some fundamental hypotheses regarding use of nearshore habitat use by juvenile salmon that can be defined. First, the area closest to natal deltas will be important as an area for the fish to transition from delta to shoreline habitats; we have defined this area as within five miles. We propose that this area is important because fish are still likely changing physiologically and so the more brackish areas near deltas would help fish finish the smoltification process. In addition, fish are likely more concentrated within this area and hence more vulnerable.

Second, habitat use by juvenile salmon is dependent upon size of the fish (Schreiner 1977; Healey 1980, 1982; Levy and Northcote 1982; Simenstad et al. 1982; Levings et al. 1986; Duffy 2003; Miller and Sadro 2003). Juvenile salmon are generally distributed along a habitat continuum based upon water depth. In general, the depth of the water occupied by the fish increasese as the size of the fish increases. We hypothesize that as fish size increases (either from growth or immigration), the fish occupy an increasing diversity of habitats including spending increasing amounts of time in neritic waters (nearshore surface waters) (Stober and Salo 1973; Fresh et al. 1979). Studies demonstrate that the smallest juvenile salmon will be primarily associated with the shallowest habitat. For example, in the Columbia River estuary, subyearling chinook occurring in shallow, intertidal habitats were smaller than subyearlings captured in deeper pelagic areas while larger, yearling migrants were more prevalent in deeper channel areas (Bottom et al. 1984; McCabe et al. 1986). Because fish are smaller close to natal deltas, we hypothesize that the bay type landscape class with its shallow, low velocity, fine grain substrate is especially important within this zone.

It is not clear whether habitat shifts occur abruptly (e.g., at a transitional size) or fish simply increase the amount of time they spend in different types of habitat (they are not as constratined to certain habitat types). Duffy (2003) hypothesized an abrupt shift in habitat at certain sizes. Simenstad ( ) suggested a similar kind of shift also occurred for chum salmon juveniles. Conversely, within the Columbia River estuary, data suggests that there is a more gradual shift in habitat use with fish spending less time in shallower areas (but not eliminating use of shallower areas) with an accompanying increase in time spent in deeper areas.

Third, throughout all areas of Puget Sound, we hypothesize that a diversity of habitat types and connectivity between habitats at multiple scales is important. Because there are a diversity of sizes of juvenile chinook salmon present in Puget sound that use a diversity of habitats, a diversity of habitat types is needed to support these fish. Simenstad (2000) and others (e.g., K. Fresh, NOAA-Fisheries, and B. Graeber, NOAA-TRT) stress that because of broad scale landscape integration, juvenile salmon must have a high degree of connectivity between landscape elements.

Fourth, in shoreline habitats, the diet of juvenile chinook is also diverse as it is in estuaries (Simenstad et al. 1982; MacDonald et al. 1987) with different types of prey dominating. Because they are larger size, chinook eat larger prey in neritic waters. As in estuaries, insects are interestingly important as prey. Diet studies suggest a broad array of insects can be eaten including. Factors that may affect which insects are eaten include habitat type, time of year, and fish size. In addition, decapod larvae are important prey for smaller fish in neritic waters with fish becoming increasingly important in diets as fish increase in size (Simenstad et al. 1982; MacDonald et al. 1987; Healey 1991).

Sub-Adult and Adult Use of Puget Sound. Eventually, juvenile chinook salmon recruit fully to the offshore waters of Puget Sound. Once in these more offshore habitats fish may only be occasionally connected with nearshore areas likely while foraging. In offshore waters, fish continue their migration to oceanic feeding grounds. Information collected on hatchery fish suggest that some hatchery fish can remain for extended periods in Puget Sound (Fresh et al. 1981; Hart and Dell 1986). The tendency for some chinook salmon to remain as extended residents in Puget Sound is well known by fisherman throughout the region. The ecology of these fish in Puget Sound and the factors that determine which fish remain as residents are unclear. For example, we do not know if particular life history strategies or populations contribute differentially to this strategy. However, we assume that this is not a unique strategy for hatchery fish but instead is followed by wild fish throughout the region. This resident strategy constitutes an alternate life history strategy that is distinct from the migrants that leave Puget Sound for ocean feeding grounds.

One factor that appears to be important to resident salmon is the production of herring and other baitfish which are important prey items of these fish (Fresh et al. 1981). Thus, factors affecting production of herring, which are in part related to nearshore habitat conditions, are likely important to this life history strategy. Similarly, specific areas such as the San Juan Islands may be more important as feeding and migratory corridors for this alternate strategy.

Clearly, adult chinook salmon must use nearshore habitats. Because adults must access spawning areas, they must use natal estuaries. While there are anecdotal reports of adult chinook in shoreline habitats while feeding (e.g., kelp habitats in the Straits), we do not have any systematic research on their habitat use in nearshore areas.

Depending upon the population and spawning location, adult chinook salmon can enter Puget Sound streams to spawn in the spring (spring run fish), summer (summer run fish) or in the fall (fall run fish). Within Puget Sound, the majority of fish enter natal rivers in the fall. Within the Lake Washington and Green River systems, fish have been reported in the estuary as early as June and as late as early October. In Lake Washington, for example, the peak of estuarine entry of fall chinook salmon is usually in August. Clearly, there can be variability within and between watersheds.

Although we know little about habitat use by adult chinook within estuaries, one feature of estuarine habitat that appears to be especially important to the adults entering freshwater is water temperature and dissolved oxygen levels. On a large scale, variability in water temperatures can affect variability in emergence timing between populations while annual variability can affect within watersheds. Of concern is the potential for water temperatures with accompanying low dissolved oxygen to delay or even kill adults. Within the Duwamish estuary, several incidences of adult chinook salmon mortality have been reported that are likely due to low dissolved oxygen levels. Sublethal levels can affect gametes. Delay can be significant as well and cause fish to arrive on spawning grounds at sub-optimal times and increase mortilaity due to such factors as predation by marine mammals in the estuary.

Chum Salmon.

Although chum salmon populations are distributed throughout Puget Sound, only the summer spawning type within Hood Canal and the Strait of Juan de Fuca has been listed under the Endangered Species Act. Summer chum return to spawn in late summer or early fall, primarily as three year or four year old fish. There is a distinct odd-even year pattern in returns of chum salmon that matches the odd-even year cycle in pinks is matched by an odd even year cycle in abundance of returning adult chum salmon (Gallagher 1979). The cyclic returns in chum salmon are hypothesized to occur because of competition between pink and chum salmon fry during early marine life (Gallagher 1979, Beachum 1993).

There has been considerable research on chum salmon in Hood Canal but very limited work on populations spawning in the Strait of Juan de Fuca (e.g., Salo et al. 1980; Simenstad et al. 1980; Bax 1983). Inferring use of habitats in Hood Canal based upon this work is problematic for several reasons. First, much of previous research began after we would expect summer chum to enter nearshore waters. Second, work in Hood Canal did not differentiate nearshore use of juvenile chum based upon race (summer vs. fall chum). While it seems reasonable to assume that the earliest migrants are summer chum, it is not clear where the line between summer chum and normal timed chum occurs. While both races rely on nearshore ecosystems, it is also unclear how such attributes as prey selection, residence time, habitat use and so on may vary between the two groups. We assume that other than obvious differences such as timing of entry into nearshore habitats, that normal timed juvenile chum are a reasonable model for juvenile summer chum. Third, large numbers of hatchery fish have been released into Hood Canal. In general, it has not been possible to discriminate hatchery and wild chum in Hood Canal so some of our knowledge of wild chum behavior has come from hatchery fish. We assume that hatchery chum are a reasonable model for wild chum.

Entry into Natal Estuaries. Summer chum spawn in late summer and early fall in nine watersheds. Fish emerge from the gravel beginning in December in some years. For all practical purposes, there is not rearing in freshwater with fry migrating directly downstream to natal estuaries, often within hours of emergence. Thus, fry arriving in natal estuaries are the same size as emerging fry or <40mm. Genetic (e.g., population of origin, when fish spawn), environmental (e.g., water temperatures), and attributes of each watershed such as hydrology, gradient, temperature regimes, basin size and so on can affect emergence timing and hence timing of estuarine entry. In general, earlier spawning and warmer water temperatures will result in fish arriving in natal estuaries earlier. One implication is that climate changes or watershed scale changes such as riparian forest cover removal that result in warmer water temperatures can result in earlier emergence timing.

Use of Natal Estuaries. One major information need for summer chum salmon is use of natal estuaries as we are unaware of published work on use of these systems by summer chum salmon fry. Based upon studies in Hood Canal, it is clear that many chum fry pass directly through natal estuaries and enter shoreline habitats. This is suggested by the fact that the size of many chum found in littoral zones is the same as that of newly emerged fry (Stober and Salo 1973; Dunford 1975; Healey 1979; Salo et al. 1980; Levy and Northcote 1982; Simenstad et al. 1982). The similarity in size between newly emerged fry and fry found in Puget Sound suggests that chum fry are able to rapidly adapt to seawater (Salo 1991).

Some studies have found larger chum salmon fry in estuaries than newly emerged fry. This suggests that either some limited rearing in natal estuaries is occurring or non-natal fish are entering estuaries from Puget Sound (Healey 1979; Levy and Northcote 1982). Both processes may be occurring. Bax (1983) found that >25% of hatchery releases north of the Skokomish River moved back onto the delta and remained there four days after release. This suggests that fish may occupy non-natal delta habitats. In 2003 in the Snohomish delta, 65mm FL chum fry were found in blind channel networks; although this suggests rearing it is possible they were non-natal fish outside the system (M. Rowse, NWFSC, unpublished data). Studies in Netarts Bay by Pearcy et al. (1989) and the Nanaimo River estuary by Healey (1979) indicate that residence time of chum salmon juveniles in estuary habitats is inversely related to the size of the fish at estuarine entry; this is the same model that chinook appear to follow. Simenstad et al. (1982) suggested that residence time of chum fry in deltas was less than 2 weeks.

It seems plausible to assume therefore that there can be a limited period of delta residence that is no more than two weeks. The proportion of any population rearing probably depends upon both annual and long term variability in environmentala and watershed conditions. One plausible hypothesis that could explain extended rearing by juvenile chum salmon is that the occurrence of rearing in a natal estuary by natal fry may depend upon timing and extent of freshwater outflow and strucutal features of the estuary. Lower flows may "retain" more fry in natal estuaries and allow them to rear. Conversely, higher flows may move more fish out into the Canal. Clearly, freshwater outflow can also affect habitat use within natal estuaries while tidal channel networks may provide low velocity refuges that retain fish.

Because use of habitats in estuaries by chinook fry and chum fry appear to be similar, it is reasonable to suggest that similar factors may be affecting residence time, habitat use and so on of the two species. While in deltas, chum salmon juveniles appear to use the same types of shallow vegetated channel networks that chinook use (e.g., Levy and Northcote 1982). This suggests that the availability of low tide refuges and access to these places is critical for chum salmon fry as well as chinook fry. Levy and Northcote (1982) found chum salmon juveniles used the same tidal channel network for several days. As with juvenile chinook, we do not how chum use the various habitat zones within the estuary- e.g., do they move around between zones or do they have to use these habitats in sequence. As with chinook, growth in estuaries varies both between and within estuary systems (Pearcy et al 1989; Healey 1979, 1982; Table 5); again, as with juvenile chinook salmon, factors affecting growth are poorly understood.

Dispersion into Hood Canal and Strait of Juan de Fuca. Chum fry eventually enter Hood Canal. We hypothesize that freshwater outflow and water circulation patterns within deltas and the receiving environment (ie Hood Canal) affects initial dispersion of fish into Hood Canal. Large floods and freshets could potentially move fish out with the freshwater plume and a significant distance from natal deltas. Potnetially, high flows could even transport fish across the Canal. Structural refuges such as tidal channels may help retain fish within natal estuaries. Fish size may also have an affect on dispersion. Newly emerged fry because of limited swimming ability may be more likely to be transported than larger fry which may have some ability to control their dispersion.

Migration through Hood Canal. Once juvenile summer chum have left natal deltas, they begin their migration to oceanic feeding grounds. As with other species of salmon, migration is not necessarily linear and directed from the Canal. For example, finding chum fry moving south after being released is evidence that fish may have more complex migration patterns than a simple linear movement from Hood Canal (Bax 1983).

Here, we have largely adopted Simenstad's (Appendix Report 3.5, Summer Chum Salmon Conservation Initiative) model of chum fry migration in Hood Canal. This model suggests that there are two modes of migration directly correlated with fish size. The first mode is for small fry (< 50-55 mm) and proposes that these fish are closely associated with shallow water <2 m deep along the shoreline. This mode is primarily associated with feeding on epibenthic prey resources (e.g., harpacticoid copepods) that are associated with bottom substrates and eelgrass. As a result, the distribution and landscape configuration of eelgrass may have an important influence on performance of chum salmon fry. For example, highly connected eelgrass may enhance chum salmon performance and a loss of connectivity of this eelgrass due to fragmentation by shoreline development may have a direct affect on chum performance. One uncertainty about the functions of eelgrass for the small summer chum salmon is that eelgrass density is at a seasonal low because of winter conditions.

The second mode of behavior applies to fry > 60 mm FL. At a size of approximately 50-60 mm FL, chum begin to make increasing use of neritic or nearshore surface waters. While they do not avoid shallow water, it appears that the range of habitats used by chum fry expands at this size to include these offshore habitats. One hypothesis is that growth rates of chum fry may be optimized at this size by a shift in habitat from shallow water to neritic habitats. Studies of chum salmon throughout their range (Salo 1991) have consistently shown that small chum eat small epibenthic invertebrates while large chum eat mostly pelagic copepods diets (e.g., Healey 1982; Simenstad et al. 1982; Healey 1979; Sibert et al. 1979; Wissmar and Simenstad 1985 year).. The epibenthic prey in shallow water areas are small and often extremely abundant ( ). These types of prey are alos supported by detritus based food webs where the organic matter originates from nearshore sources of carbon. This type of prey may provide a bioenergetically rich prey source for small fish but the small size of this prey may be less optimal for larger chum.

One uncertainty in any migration model of chum in Hood Canal that requires future research is the role of non-natal estuarine systems, including pocket estuary systems that chum can encounter along their migration route. There is an extensive system of these estuary systems in the Canal. One possibility based upon recent work by R. Hiroschi (personal communication) is that fish may exploit some of these non-natal estuarine habitats along their migration. Mason (1974), however, reported extensive use of a small delta in British Columbia by chum fry that may have originated from outside the delta since no spawning was reported in the system during the duration of his study. Such use of these systems would suggest that connectivity of these non-natal systems by eelgrass might represent an optimum habitat architecture for summer chum salmon in Hood Canal. If this model is correct, then protection and restoration of summer chum habitat in Puget sound could adopt this strategic approach.

Migration rates of chum salmon along Hood Canal average between 4 and 14 km per day and generally decrease as the season progresses. These rates were developed primarily for normal timed chum so it is not clear whether migration rates are faster or slower earlier in the year. Two hypotheses have been proposed to explain migration rates between and within years. One hypothesis is that migration rate is a function of surface outflow which is determined by strength and duration of wind from the south (Bax 1983). The second hypothesis is that migration rate is a function of foraging success (Simenstad et al. 1980). This hypothesis suggests that as prey resources increase and foraging success increase, fish migration decreases. Both mechanisms may in fact be true and may operate simultaneously.

Migration rate, especially for the smaller sizes of chum, may be an important performance measure for summer chum because it may relate directly to foraging, growth rate and in turn survival. Because of their small size, factors that increase growth rates should translate directly into larger fish which would increase survival rates for the chum salmon. Thus, abundant prey could slow migration rates which would result in larger fish. In addition, because marine survival rates are directly correlated with size of ocean entry, factors that produce larger fish leaving Hood Canal may be important. Thus, slower migration rates which produce larger fish may enhance survival. While this seems to be a reasonable hypothesis, it is not clear if differences of several days or a week in exiting Hood Canal are significant.

Further, it is not clear if neritic and epibenthic prey communities respond similarly to the same controlling factors in Hood Canal. Although we cannot directly manipulate any sort of wind mediated migration rate, we can potentially affect migration rate, foraging success, and growth rates by the site and landscape scale habitat conditions present in Hood Canal in shoreline areas. For example, as we have noted, the architecture of habitat in shoreline areas may be key to the early life history. It is probable that these same actions would not have the same affect on neritic types of prey. Enhancing growth during the initial stages in Hood Canal may present the best opportunity for recovery actions in the nearshore.

The importance of ecological interactions to summer chum survival is unclear. While the importance of food web processes is obvious, it is not clear whether competition is important to chum. On the one hand chum are one of the few species present in abundance early in the year. Pinks are present at the same time and may be comptitiors especially in neritic waters where neritc prey are used by both species. The correlations between between pink production and chum and chinook production suggests that some interaction between species may be occurring. It is not clear the nature of this interaction if it is real. Predator populations are presumably low at this time of year as yearling salmonids have not entered Puget Sound in large numbers. Further, bird foraging in winter is limited.

Sub Adult and Adult Use of Nearshore Habitats. Once chum exit Hood Canal we have no information on their habitat use. We do not know if they are associated with nearshore habitats or and how sub basins to the north function for summer chum. As some chum have been observed in Puget Sound late in the fall (Fresh et al. 1981; Hartt and Dell 1986), chum appear to exhibit a resident strategy similar to chinook. It is not clear whether this characterizes Hood Canal summer chum.

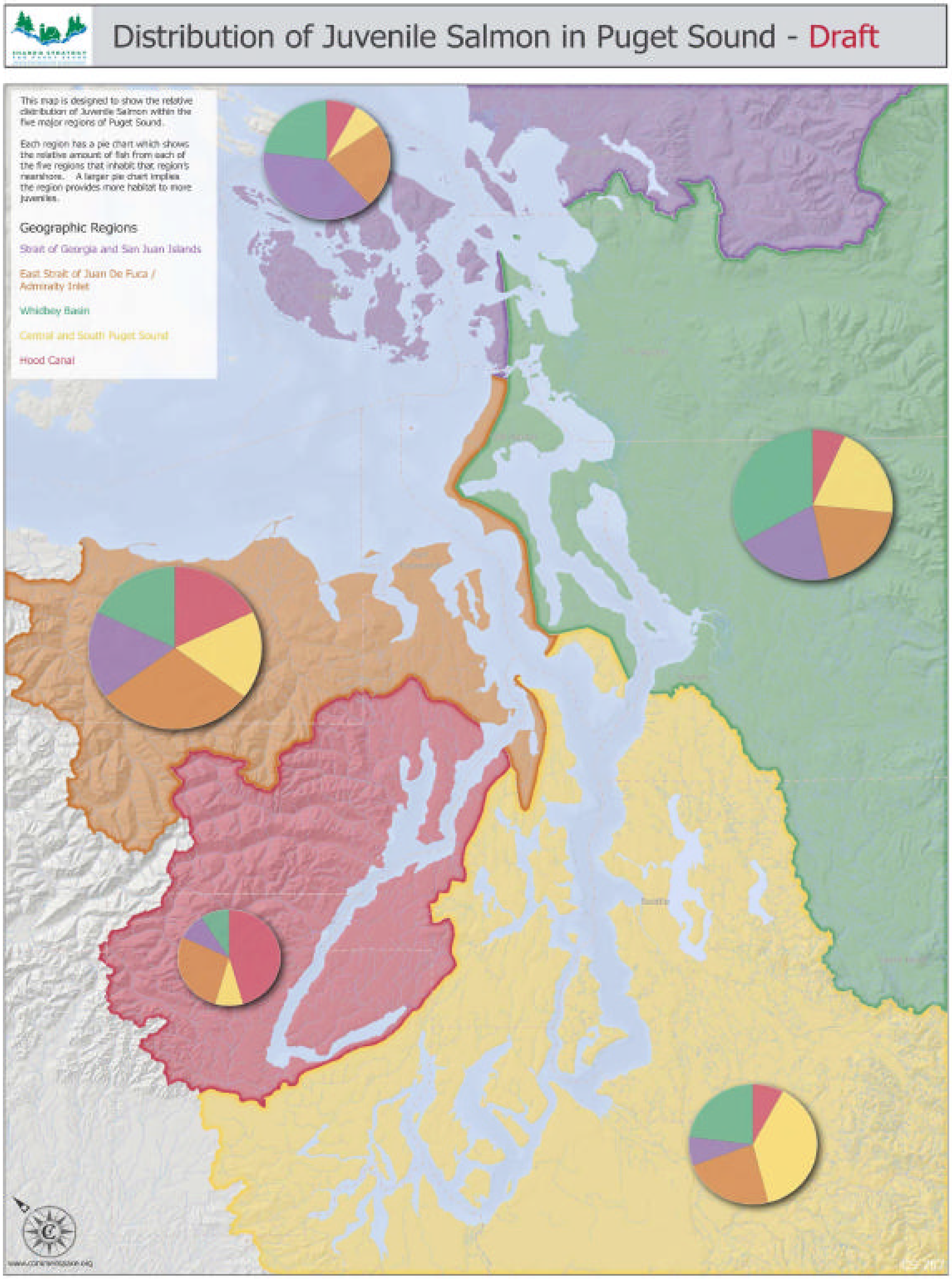
As with chinook salmon, adult chum make use of at least estuary habitats. Similar to chinook, they are entering estuaries at times of year when flows are low, potentially affecting access. In addition, seasonal temperatures are also expected to be greatest at this time of year which may also affect accessibility and subsequent survival in freshwater of adult summer chum.

f) Geographic Distribution- Differences Between Subbasins

Research conducted in the last several years in Puget Sound using recovery of coded wire tags (CWT) from hatchery fish has found that juvenile hatchery chinook salmon disperse widely throughout Puget Sound after passage through natal deltas. For example, Fresh et al. (2003) found CWT hatchery produced juvenile chinook from 13 different release locations in Sinclair Inlet, a small bay with no natal chinook populations. Nearly one-third of the CWT hatchery fish recovered in deep South Sound originated from outside of South Sound. Additional research has revealed similar results. For example, a study by Brennan and Higgins (2003) in nearshore waters of central Puget Sound observed and captured juvenile chinook salmon from 22 different hatcheries and 13 WRIA's (2004 Pacific Estuarine Research Society (PERS) conference abstract); and CWT recoveries in the San Juan Islands from adult salmon between 1978 and 2001 revealed fish from many different populations, including adult chinook salmon from the Upper, Central and Lower Columbia River, the Snake River in Idaho and chinook salmon from throughout Puget Sound (data from the Pacific States Marine Fisheries Commission, RMIS database). Thus, at least for hatchery fish, each region of Puget Sound supports both natal and non-natal populations (Figure 4).

Salmon biologists believe it is reasonable to assume that naturally produced fish exhibit similar types of dispersal patterns (K. Fresh, NOAA Fisheries) and that each region of Puget Sound supports both natal and non-natal populations. The degree of support provided by any one region for different populations is unknown, although continuing analyses of CWT chinook salmon juveniles will provide additional insight in the near future. Based upon personal communications with investigators doing this work in Puget Sound, we propose the following hypotheses about non-natal use of Puget Sound:

1. Areas immediately adjacent to natal estuaries are especially important to natal populations, although they can be also used by non-natal fish,
2. Major estuaries are used by non-natal populations,
3. Regions south of entry points of populations into Puget Sound are less important than areas to the north, and
4. Importance of areas to the south of entry points of populations into Puget Sound decrease with distance.



Source: Semi-quantitative portrayal of distribution hypotheses suggested by Kurt Fresh, NOAA-Fisheries, NWFSC and Bill Graeber, NOAA-TRT (personal communication).

Figure 4. Draft distribution of CWT-recovered chinook salmon juveniles in Puget Sound.

g) Response of Salmon to Nearshore Habitat Conditions

The endpoint of the conceptual model is the response of salmon to nearshore ecosystem conditions. The response of the salmon is a cumulative result of all the habitat conditions experienced by salmon during their transit through nearshore ecosystems. This response clearly depends upon where the fish have come from (e.g., population and life history strategy) and then where they go after they leave nearshore habitats. What happens to the fish during occupation of nearshore habitats can have an important influence on performance in later life stages. Here, we consider the response of salmon to habitat conditions at three scales: individual fish, populations, and ESU (Figure XXX). Although the primary concern is status or response of the ESU, we propose that is necessary to consider how individuals and populations respond to understand ESU response.

Response of Individual Salmon to Nearshore Habitat.

As we discussed previously, habitat consists of attributes or features that can be classified based upon how they affect the opportunity for individual salmon to use that habitat and the capacity of that habitat to support salmon (Figure XXX). The product of capacity and opportunity affects the value of the habitat to individual salmon. Although there are a number of ways to measure performance, value of nearshore habitat to individual salmon is mostly directly measured as survival of individuals. Survival ultimately defines what fish will be successful and contribute to succeeding generations. Nearshore habitats can affect survival in two ways. First, mortality can occur during passage through nearshore ecosystems. Second, it can affect survival potential later in life. For example, the size and timing of fish exiting Puget Sound can affect survival in later stages during ocean residence.

As illustrated by our conceptual model, the ability of nearshore habitats to promote survival not only depends upon the habitat but upon characteristics of the fish themselves including their species, population of origin, and life history strategy. Ideally, survival could be directly measured or indirectly measured through measuring opportunity and capacity which are directly linked to condition of the habitat. This type of analysis is not possible at this time.

Response of Populations.

Conceptually, nearshore habitats, like all habitats used by salmon during their life, contribute to the viability of salmon populations. NOAA Fisheries (McElhany et al. 2000) defined a viable population as one that has a negligible risk of extinction over a 100 year time period. Thus, changes in viability are used to evaluate affects of recovery actions. Four performance criteria (Viable Salmonid Population or VSP criteria) are used to define viability (McElhany et al. 2000): abundance, productivity, spatial structure, and diversity. All four VSP criteria are critical to the viability of salmon populations, all are interrelated, and levels of all four attributes in aggregate define extinction risk or the likely persistence of the population or ESU.

Briefly, *abundance* is a measure of the number of members in the population (e.g., numbers of spawners or returning adults), while *productivity* is the rate of growth of the population over a given time interval. Productivity can also be expressed as life-stage specific survivals, since the cumulative effects of those survivals results in a population's growth rate over time. Evidence clearly suggests that estuarine habitats contribute to the abundance and productivity of salmon populations (MacDonald et al. 1988; Reimers 1973; Magnusson and Hilborn 2003). *Spatial structure* refers to the geographic distribution of individuals in the population and the processes that generate that distribution. Salmon populations clearly exhibit complex geographic structure that can be defined at multiple spatial scales (e.g., within a natal estuary and between sub-basins) *Diversity* consists of the variability in life history and discrete genetic traits exhibited by members of a population. Diversity in salmon life histories exists along a continuum and includes individuals, subpopulations, populations, ESUs, and species. Spatial structure and diversity are closely related. A major factor affecting the number and quality of life history strategies (quality is defined as how successful the trajectory is at producing recruits) present within a population will be the distribution and quality of habitats that can potentially be used (NRC 1996). In order for a population to use diverse habitats requires that the habitats be available (spatial structure) and that the right fish must be available to use these habitats (e.g., life history strategy).

Populations that have a lot of members and a positive population growth rate are more likely to persist then populations that do not have these characteristics. Distributing members of a population through an array of habitats at multiple scales also helps reduce the vulnerability of the population to shifts in environmental conditions (McElhany et al., Hilborn et al. 2003). Along with spatial structure, having high phenotypic diversity (e.g., lots of members using each life history strategy) helps buffer populations from environmental variability (Taylor 1990, Hilborn et al. 2003).

Nearshore habitats affect population viability by helping to determine which individuals within the population spawn and therefore contribute to succeeding generations. The processes that determine adult survivors occur in all life stages, are biological and non-biological, and operate at multiple scales of space and time.

The ability of each individual to survive is in part affected by the distribution, quality, and amount of nearshore habitats available to that individual. Individuals within a population can be aggregated into different life history strategies. The success of each life history strategy will depend upon the success of individuals associated with that life history strategy which in turn depends upon the availability of appropriate habitats (for that strategy), the landscape context of that habitat (e.g., order habitats are available), the accessibility and quality of that habitat. If the habitats do not exist because of either natural or anthropogenic factors, then population members cannot use them and the number of members using distinct life history strategies can potentially be reduced or ultimately eliminated from the population. Conversely, even if nearshore habitats are available, the appropriate life history strategies must be available to use these habitats. For example, if complex natal estuary habitat is available for the delta fry strategy, the freshwater habitats must be successful at producing the fry to use these habitats.

Fundamentally, the intent of any action is to produce more spawning individuals (increase abundance) of one or more populations. Historically, the focus of salmon management was on maximizing the increase in abundance of individuals (Fresh et al. in press). Each action, however, can be defined more specifically in terms of how it affects viability of a particular population (in essence how it creates more salmon) depending upon the circumstances of that action (e.g., whether it affects habitat opportunity or capacity). For example, from the perspective of the Snoqualamie chinook salmon population, actions taken in South Puget Sound (south of the narrows) will primarily affect spatial structure and diversity of the population because it will not substantially change abundance or productivity levels. Actions taken in the Snohomish Estuary that affect the rearing capacity of delta fry will change the composition of life history strategies. Because it increases the number of members of the dominant life history strategy, abundance and productivity levels can be affected. Actions that increase abundance levels of non-dominant life history strategies primarily affect life history diversity and spatial structure because they have a relatively small affect on overall population abundance, at least over the short term.

RULES FOR HOW VIAILBITY CAN BE AFFECTED BY DIFFERENT ACTIONS (IN PROGRESS) (NOT SURE IS DOABLE)

Each life history strategy will contribute differentially to the population based upon the cumulative affect of all natural and anthropogenic factors affecting the habitat. The success in aggregate of all the life history strategies over long time scales then determines the viability of that population. For example, if all life history strategies within a population are highly productive, population viability can be high while if only one strategy is successful, viability will tend to be lower and the population will be more at risk to extinction events in the future. Over long time and short scales, conditions will change that will affect the success of each strategy. As a result, strategies that have low productivity during a particular time period may become more productive as large scale environmental changes occur.

Response of ESU's.

ESU's are composed of populations. Thus, it is the aggregate response of all the populations within an ESU that will determine whether or not there is a change in viability of an ESU. There is not a correct or single mix of populations associated viability within an ESU that will determine status of the ESU. Conceptually, the viability of enough populations within an ESU has to increase for ESU viability to increase.

4. THREATS, STRESSORS, AND EXISTING MANAGEMENT ACTIONS

Dan Averill, Scott Redman, and Doug Myers, Puget Sound Action Team

In this section we describe various threats and impairments to nearshore and marine ecosystem processes and salmon habitats and functions. We also provide brief descriptions of existing management actions. These materials complete our introduction to the various portions of our conceptual model (Figure 4-1).

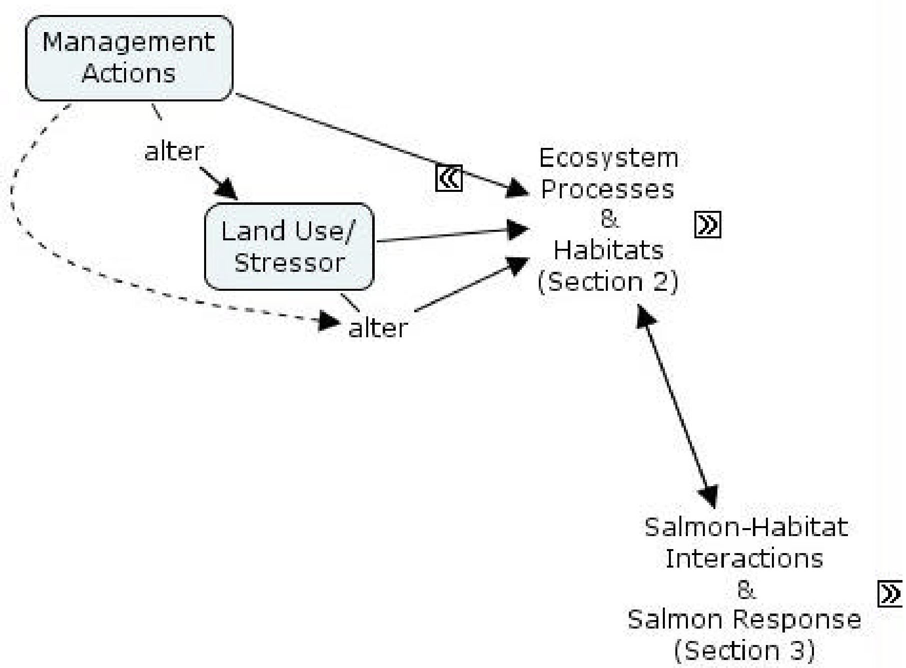


Figure 4-1: **The human stressor and management portion of our conceptual model**

In this section, we briefly discuss some of the historical human activities, policies, and other factors that have contributed to habitat and ecosystem change in the Puget Sound region (Section 4.1); discuss the threats (potential for harm) and impairments (currently degraded or lost function or process) that we believe to be the most critical concerns for region-scale nearshore and marine aspects of salmon recovery (Sections 4.2 to 4.9); and introduce some of the key existing management authorities that can address these threats and stressors (Section 4.10).

Our evaluation of threats and impairments was informed by and followed the organization of, the PSAMP conceptual model (Newton et al., 2000). We considered the relevance of each of the stressors listed in the PSAMP model to salmon viability when viewed at the regional scale, and evaluated the effects of various candidate stressors on the four functions of nearshore and marine habitats for salmon. Our conceptual model (derived from PSAMP) of the associations between stressors (categories of mechanisms of threat and impairment) and human actions is presented in Appendix C. Two overarching considerations were important to our thinking about and review of stressors' potential effects on salmon:

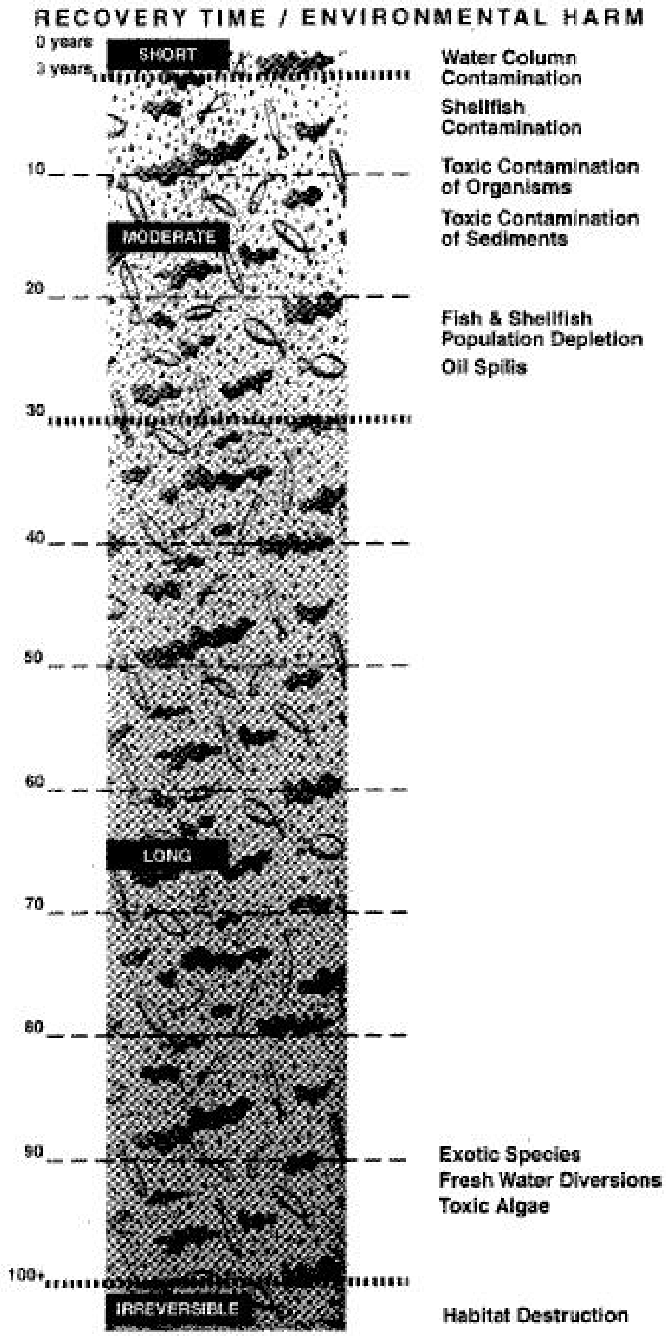
- Human activities impart stressors to the nearshore and marine environment that can persist for varying lengths of time. Often, if the activity causing the stressor is removed, the environment may be allowed to recover or regenerate. The recovery time required to remediate environmental harm can be highly variable. For example, the environment may recover from a stressor such as shellfish contamination in a moderate period of time (3-10 years); whereas the environmental recovery time for a stressor such as habitat destruction may be irreversible (100+ years) (Figure 4-2) (PSWQA, 1994).

- In estuarine and nearshore environments many stressors can co-occur because these areas have been the focus of much human development and activity over the past 150 years. Effects of the multitude of human-induced stressors on salmon are compounded in estuarine areas because the fish are naturally stressed as they use and pass through estuaries due to physiological changes associated with the transition from living in fresh to salt water environments (from Aitken 1998). We presume this compounding of human and natural stresses also confronts fish that accomplish this transition in areas away from the estuaries of their natal rivers.

By acting on the functions that salmon receive from nearshore and marine environments, the stressors discussed in this section can affect the viability of salmon populations in a variety of ways. In some cases, a stressor might jeopardize the viability of a particular life history type within a population and, therefore, limit the population's spatial structure and/or diversity. For example, the loss of river estuary and proximal nearshore habitats can threaten the viability of the delta fry and fry migrant segments of a population even though high quality pocket estuaries may be abundant in the more distant reaches of Puget Sound. In other cases, the same stressor (loss of estuary habitat) may reduce the productive capacity of a sub-basin and thereby jeopardize the abundance and/or productivity of a population.

The following stressors are presented in this section and carried through to a landscape analysis in Section 6:

- Loss and/or simplification of deltas and delta wetlands
- Alteration of flows through major rivers
- Modification of shorelines by armoring, overwater structures and loss of riparian vegetation
- Contamination of nearshore and marine resources
- Alteration of biological populations and communities
- Transformation of land cover and hydrologic function of small marine discharges via urbanization
- Transformation of habitat types and features via colonization by invasive plants



Source: Puget Sound Water Quality Authority and British Columbia Ministry of the Environment, 1994.

Figure 4-2. Recovery time based on a selection of environmental stressors.

4.1 Historical considerations

Human activities and development patterns have modified, and continue to alter, nearshore ecosystems by constraining, redirecting, disrupting or eliminating the processes that control the delivery and distribution of sediment, water, energy, organic matter, nutrients and other chemicals in Puget Sound's nearshore environments. (A more detailed account of these patterns and the motivations behind them is found in Appendix D). These activities and development patterns were driven by the social, cultural, and economic values of the societies, communities, and individuals that resided in or utilized these nearshore marine ecosystems over time. Negative feedbacks from rapid development and resource extraction prompted environmental legislation in the early 1970's corresponding to a similar awakening nationwide. Our more recent commitment to restoration of nearshore processes signals additional changes to the social, cultural and economic values that are currently held by many Puget Sound residents. It is important to acknowledge that many impairments to Puget Sound's nearshore landscape occurred through practices that were considered appropriate for the time and reflected the social, behavioral and cultural values held by the people. Our ability to restore nearshore habitats and functions will similarly be aided or obstructed by those values now.

4.2 Loss & simplification of estuaries and wetlands

Stressor: Loss and simplification of river mouth estuaries, deltas, wetlands

Examples of *activities* contributing to this stressor:

- Industrial and residential development,
- Agricultural activities (e.g., diking, filling, revetments, tidegates, other water control structures),
- Channelization,
- Construction activities (e.g., jetties, training walls).

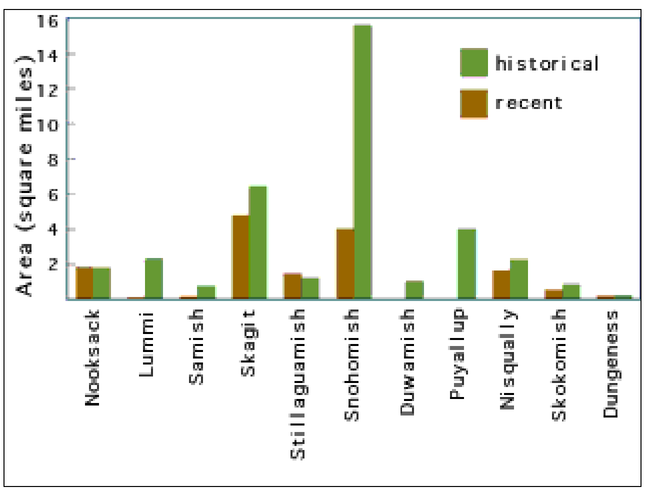
Working Hypotheses

1. Activities such as diking and straightening of estuarine/lowland channels results in lost floodplain area, as well as constrained and accelerated movement of water through the channels,
2. This can lead to increased erosion potential by transporting sediments and organic material, and ultimately an altered arrangement of drainage channels,
3. These changes reduce or degrade the functions estuarine habitats provide for juvenile outmigrant salmon (e.g., feeding and growth, refuge, physiological transition, migratory corridor), especially those of the delta fry life history type.
4. Agricultural and development activities impact sub-adult and adult anadromous bull trout by impacting rearing and migration, and overwintering habitats.

Effects on processes and habitats

Humans throughout the ages have populated large and small estuaries in Puget Sound. Historically, such locations were optimal for a variety of reasons, including habitation, commerce, food, and access to Puget Sound waters. However, habitat conditions of the major (and lesser) river estuaries of Puget Sound have changed considerably over the last century.

Estuaries in Puget Sound are regions that attracted early agricultural and industrial development and because of activities such as diking and filling, greater than 73% of the river delta wetlands have been lost in the last 100 years (People for Puget Sound 1997). Bortleson et al. (1980) compared historic and present-day maps and reported the loss of subaerial wetlands and intertidal areas for 11 major Puget Sound estuaries. A majority of the 11 estuaries showed a loss of *subaerial* wetlands, of which three estuaries (Lummi, Snohomish and Puyallup) exhibited a significant loss totaling 5km^2 or more (Bortleson et al., 1980). Diking was identified as the primary causative agent. The Nooksack and Stillaguamish estuaries exhibited a slight increase in subaerial wetland area. The Lummi, Skokomish and Dungeness estuaries showed relatively minor loss of *intertidal* area, whereas the Duwamish and Puyallup estuaries exhibited nearly a complete loss of intertidal area (Bortleson et al., 1980). Extensive dredge and fill operations were identified as the primary causative agent. The extent of the loss of wetland habitat from the late 1800's through the 1970's for many of the major estuaries listed in Section 2.3 is shown in Figure 4-3**.**



Source: People for Puget Sound's (1997) *The Loss of Habitat in Puget Sound* (after Bortleson et al. 1980).

Figure 4-3. Historical changes of wetland area in major river deltas of Puget Sound.

The amount of habitat loss between these large river estuaries is variable, as are the categories of land use prompting the decline. For example, the Duwamish and Puyallup estuaries are proximate to our largest urban centers, and as a result of human activities such as industry these estuarine habitats have experienced considerable losses. The change in wetland habitat area between historical and current (1970's) condition in the Snohomish estuary is substantial. However, many of the agricultural lands made possible by historical diking are no longer actively worked. Thus, the Snohomish estuary offers significant opportunity for restoration.

Collins et al. (2003) utilized archival sources and field investigations to create GIS maps of the historic riverine environment for several systems in north Puget Sound. Prior to extensive modification of the landscape by settlers, the large floodplain wetlands and extensive estuarine marshes "accounted for nearly two-thirds (62%) of the valley bottom" of the Snohomish River (Collins et al, 2003). The Nooksack mainstem exhibited a similar distribution of habitats, historically. A less complex channel pattern now exists for the upper Nooksack mainstem and the Skykomish River, due in part to levees and isolating meanders (Collins et al, 2003). Historically, estuarine wetlands were extensive in the Skagit-Samish delta, consuming an area more than twice that of the Nooksack, Stillaguamish and Snohomish deltas, combined (Collins et al, 2003). Diking and draining of wetlands has reduced the area. The loss of side channel regions and riparian vegetation in floodplains and estuarine areas can be attributed to such activities as agricultural practices (USFWS 2004). Diking and tidegates negatively affects tidally influenced habitats by limiting saltwater exchange with historic estuaries, such as with the Skokomish River (USFWS 2004). Fish passage and prey species can be impacted.

Effects of dike construction and marsh conversion are often most obvious on the landward side (e.g., converted land). Less visible are the *seaward* effects of such an activity. Hood (2004) studied the *seaward* effects of dike construction and marsh conversion on estuarine marshes and tidal channels in the Skagit River delta via analysis of historical photos. Three separate areas were studied: Wiley Slough area, South Fork Skagit delta, and North Fork delta. Hood (2004) reported "dikes indirectly affect sediment dynamics and channel geomorphology in seaward areas as a consequence of tidal prism loss that results from the dikes directly excluding tidal waters in landward areas." More tidal channel surface area was lost seaward of dikes than landward of dikes for each study area, and reduced or lost channel sinuosity likely leads to diminished channel habitat diversity (Hood 2004). As a result, aquatic species such as Chinook salmon are affected by this loss of habitat.

Effects on salmon functions; effects on bull trout

Weitkamp *et al*. (2000) reported that the filling and channelization of the Green and Duwamish River estuary is likely to substantially impact the Chinook salmon populations because shallow water habitat and migration corridors are reduced, and the simplified estuarine habitat could reduce survival of the portion of the juvenile Chinook salmon populations that remain in estuaries for extended periods of time (e.g., delta fry and parr migrant life history types). Furthermore, the substantially reduced estuarine habitat coupled with a loss of complexity may have resulted in reduced rearing areas and a loss of some life history types (Weitkamp 2000).

In his literature review, Aitken (1998) identified jetties, training walls, filling and dredging as some of the human activities that result in a loss of intertidal rearing habitat and which negatively impact juvenile Chinook and chum salmon through a reduction in one function: feeding and growth. A Canadian study in the Fraser River estuary revealed juvenile anadromous salmonids such as Chinook and chum make use of all tidal channel habitats within the estuary, “and any diking of that habitat would reduce the rearing capacity of the estuary” (Aitken 1998). The degree to which salt water penetrates an estuary, as well as the distribution and circulation of organic materials from outside the estuary, can be altered by jetties and training walls (Aitken 1998). Several studies listed by Aitken (1998) document the potential of these human activities to promote shifts in species assemblages, reduce prey resources, eliminate rearing habitat, and alter migratory behavior.

Research completed by Yates 2001 (NOAA Fisheries unpublished annotated bibliography) at a north Puget Sound channel jetty and causeway concluded that both structures acted as a physical barrier to outmigrating juvenile Chinook salmon because the amount of transitional and shallow habitat often used by these salmon was reduced. In essence, the jetty and causeway acted as barriers and the juvenile Chinook were forced to swim into regions with higher salinity before physiologically prepared (Yates 2001, NOAA Fisheries unpublished annotated bibliography). As such, the physiological transition, migratory corridor, and potentially the feeding and growth and refuge from predators and extreme event functions of juvenile Chinook and chum salmon can be affected. Inaccessibility to pocket estuaries is caused by activities in tidal wetlands such as tide gates, roads, and fill (Beamer *et al*. 2003).

A reduction in habitat complexity via diking and channelization, reduced riparian vegetation, and reduced large woody debris due to agricultural practices and development have impacted anadromous bull trout. Diking of estuaries and floodplains in the Nooksack, lower Skagit, Stillaguamish, and Puyallup regions have obstructed access to historical wetland regions and have affected anadromous bull trout foraging, migration, and overwintering habitat (USFWS 2004). The lower Skagit region was historically a productive salmon rearing region, with sloughs, low-velocity overwintering areas and connectivity, but much of this has been lost. Thus, anadromous bull trout are affected because the period of time these prey species (i.e., juvenile salmon) occupy nearshore environments has been curtailed (USFWS 2004). Sub-adult and adult anadromous bull trout foraging, migration, and overwintering habitat has also been reduced in the Stillaguamish and Puyallup estuaries. Diking, channelization, and development have impacted the Lower Skokomish River and estuary as well. Thus, habitats important to bull trout for foraging, migration and overwintering have been degraded (USFWS 2004). It is also believed anadromous bull trout have been impacted by the decline of forage fish and loss of habitat in Hood Canal and the Strait of Juan de Fuca (USFWS 2004).

Table 4-1. Effects of Loss and Simplification of Estuaries and Wetlands on Ecosystems and Salmon and Bull Trout Functions

Activities	Effects on nearshore and marine ecosystem processes and habitats	Hypothesized effects on salmon and bull trout functions
Industrial and residential development	• Loss of subaerial wetlands and intertidal areas • Habitat simplification (e.g., channel structure) • Loss of riparian vegetation, LWD • Inaccessibility to pocket estuaries	• Reduced rearing areas • Possible loss of some life history types
Agricultural (diking, filling, tide gates, etc)	• Loss of subaerial wetlands, marsh, and intertidal areas • Altered tidal prism (hydrology) • Altered sediment supply; dynamics • Loss of channels • Loss of organic matter, reduction in detritus • Habitat simplification (e.g., channel structure) • Loss of riparian vegetation, LWD • Loss of tidal channel surface area • Inaccessibility to pocket estuaries	• Altered fish passage • Altered prey species resources • Reduced shallow water habitat and migration corridors • Reduced rearing areas • Reduced feeding and growth • Shift in species assemblage • Altered foraging, migration, and overwintering habitat
Channelization	• Habitat simplification (e.g., channel structure) • Loss of channel sinuosity	• Reduced migration corridors • Reduced rearing areas
Construction (jetties, training walls)	• Loss of intertidal rearing habitat • Physical barrier to migrating salmon	• Reduced feeding and growth • Altered migratory behavior • Reduced rearing areas • Shift in species assemblage • Reduced prey resources • Altered physiological transition • Altered refuge

4.3 Alteration of flows through major rivers of Puget Sound

Stressor: Alteration of flows through major rivers of Puget Sound

Examples of *activities* contributing to this stressor:

- Dams
- Diversions
- Channelization
- "Re-plumbing" of stream and river networks
- Forestry activities
- Development of lands

Working Hypotheses

1. Changes in the timing, magnitude, and quality of flow of freshwater and sediment affects water quantity, water quality and the amount and types of sediments delivered to Puget Sound.
2. Reductions in water quantity can reduce the quantity of useable habitat areas and increase water temperatures. Reduced sediment delivery to estuaries can lead to shifts in aquatic vegetation communities.
3. The effects of these changes on juvenile Chinook and chum salmon include altered feeding and growth (e.g., reduced food sources available to salmon), alteration of refuge locations, and alteration of areas for physiological transition.
4. Dams, diversions and development impact sub-adult and adult anadromous bull trout by impeding or limiting migration, altered hydrology and reduced channel complexity.

A variety of activities have altered freshwater contributions to Puget Sound over the last 150 years. Some examples include the damming of rivers and streams, water diversions, channelization, "re-plumbing" river and lake networks, and reduced groundwater recharge. Consequently the estuarine, delta and nearshore environments are affected in several ways.

Freshwater contributions are an important part of the hydrologic cycle within Puget Sound and are a driving force in controlling the estuarine environment (PSAT 2002). In addition, freshwater inputs directly impact water temperature and salinity, and the vertical and horizontal patterns within Puget Sound for these variables (PSAT 2002).

a) Dams and other flow alteration mechanisms affect runoff timing and peak flows

Effects on processes and habitats

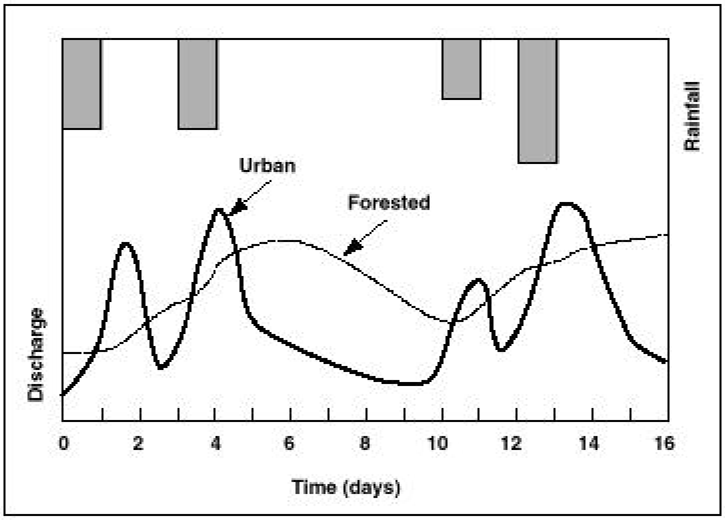
Dams and other flow alteration practices (artifacts of urbanization) can lead to altered freshwater hydrographs, which can affect the quality and quantity of freshwater reaching the estuarine and nearshore environments. Freshwater flows are usually more variable in unmodified rivers as compared to rivers with dams where higher flows are often moderated during parts of the year. Dams and diversions can reduce the magnitude and frequency of elevated flows. Dams and diversions can also affect downstream habitats by altering the distribution of large woody debris (USFWS 2004).

Of the rivers emptying into Puget Sound, the Skagit River discharges the greatest quantity of sediment and the Deschutes River the least (Downing 1983, NOAA Fisheries unpublished annotated bibliography). The size and shape of a delta face are affected when dams prevent the downstream movement of sediments. Cushman dam on the Skokomish River diverts 40% of the annual average freshwater flow from ever reaching the delta (Jay and Simenstad, 1996). Jay and Simenstad (1996) compared pre-diversion (1885) and post-diversion (1941 and 1972) deltaic bathymetric surveys and habitat, implications for the sediment transport regime, and net gain and loss of deltaic surface area and habitat. Their surveys suggested deposition has occurred on much of the inner delta and erosion on much of the outer delta. Many of the historical bathymetric change cross-sections (9 of 12) revealed a steepening of the delta surface, apparently "caused by a loss of sediment transport capacity in the lower river and estuary combined with steady or increased (due to logging) sediment supply" (Jay and Simenstad, 1996). In addition, a 15-19% loss of "highly productive low intertidal surface area" habitat between 0.6 m below MLLW and 0.6 m above was observed, as well as an estimated 17% decrease in area of eelgrass beds. The dams on the Elwha River have impacted the estuary and beach morphology. The recruitment of fluvial sediment has been lost, promoting the erosion of at least 366 meters (1,200 feet) of shoreline between 1939 and 1994 (USFWS 2004).

Forestry and agricultural practices and land development can also contribute to altered hydrographs. Forestry practices such as timber harvest and road building can increase peak flows, as well as increase runoff and decrease infiltration when soils are compacted (EPA 2000). The historical practice of constructing splash dams on streams to facilitate transport of logs downstream also resulted in estuarine impacts (USFWS 2004). Historically, the Samish River contained numerous forks and sloughs within the delta region, all too small to float logs downstream. To facilitate movement of logs downstream, a single channel was created and the remaining channels and sloughs within the delta blocked off (USFWS 2004). In addition, clearing and removal of LWD (and LWD jams) was a common practice in larger rivers such as the Skagit and Nooksack (USFWS 2004). Agricultural practices can affect peak and low flows by increasing storm runoff timing and lowering water tables, respectively (EPA 2000). Finally, development of lands for urban uses can increase impervious surfaces and thereby reduce infiltration, accelerate surface flows to freshwater channels, and generate earlier, larger and more intense peak flows (Figures 4-4 and 4-5) (EPA 2000). This can affect estuarine and shoreline receiving waters.

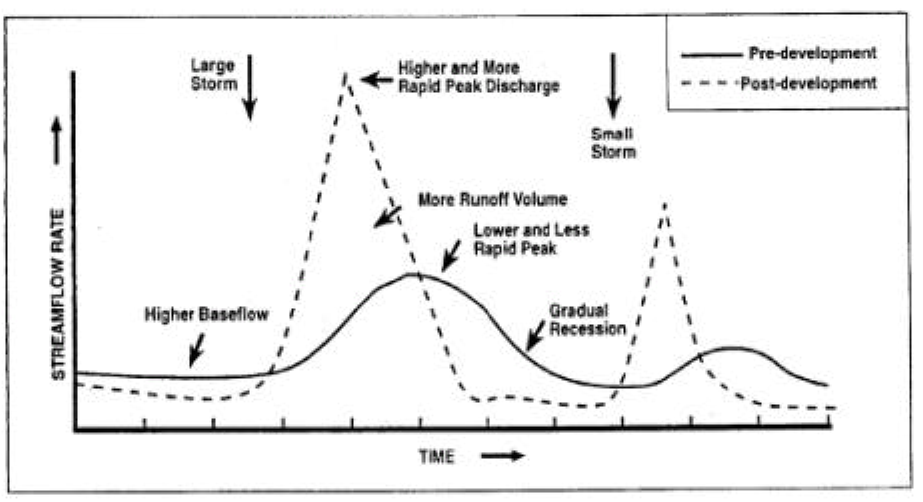
Effects on salmon functions; effects on bull trout

Dam construction can alter estuarine habitat types such as marshes and blind channels in such ways as a loss of marsh and delta surface, and channel erosion and incision of blind channels (K. Fresh, unpublished data). A gradual, or intermediate salinity gradient is especially important in estuaries for juvenile salmon during the rigors of physiological transition from freshwater to saltwater (Aitken 1998). Consequently, the reduced area for transitional salinity concentrations within the delta could negatively impact juvenile salmon such as Chinook and chum when utilizing the delta for osmoregulation functions. Aitken (1998) reported river discharge and surface outflow as one of the four potential factors suggested by the scientific community as limiting the residence time of juvenile salmonids such as Chinook and chum salmon while in estuaries.



Source: EPA Watershed Analysis and Management Project, Hydrology Module, 2000.

Figure 4-4. Difference in response by two different freshwater systems during the same storm event.



Source: Schueler, 1987.

Figure 4-5. Conceptual freshwater hydrographs pre- and post-development.

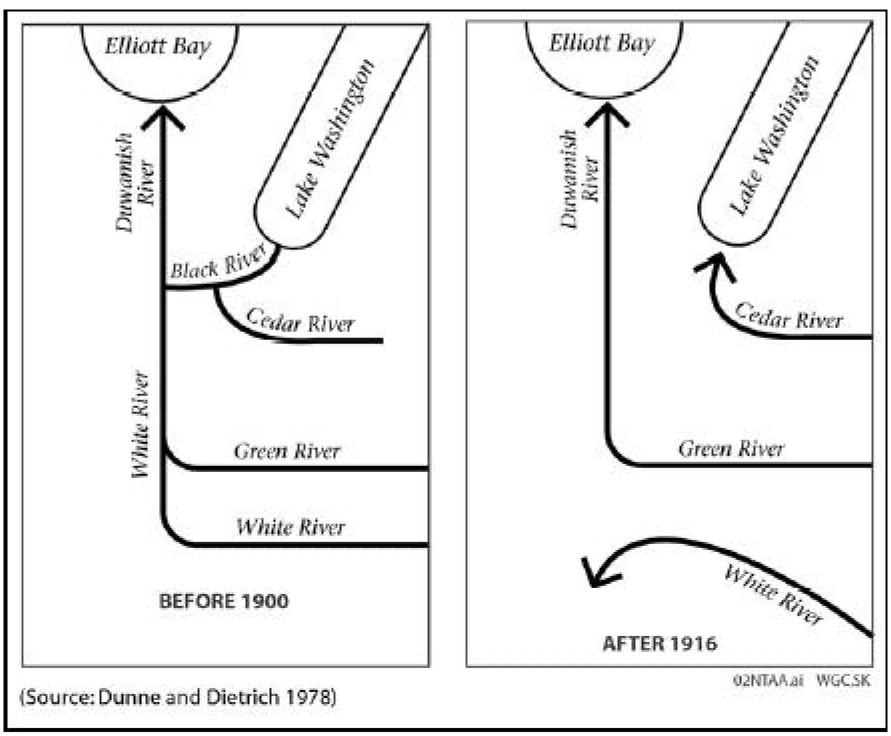
Barriers such as dams limit population interaction "and may eliminate life history forms of bull trout" (USFWS 2004). Population connectivity and viability can be impacted. Dams on the upper Skagit River have prevented the movement of large woody debris to the Lower Skagit River (USFWS 2004). As a result of this and historic wood removal, the habitat complexity in the Lower Skagit River mainstem and estuary has been reduced over time. The practice of repeated splash damming caused channel scouring and long-term impacts to bull trout habitat (USFWS 2004). The Cushman dams on the Skokomish River have reduced the flow of water reaching the delta, and thus affected the sediment regime and the shape of the delta. Consequently, the intertidal zone has been impacted. Biological productivity and the size of eelgrass beds in the Skokomish estuary has been reduced; thus, bull trout are impacted because herring, an important prey species, rely on eelgrass for spawning (USFWS 2004). The loss of eelgrass reduces foraging opportunities for bull trout in the Skokomish estuary (USFWS 2004). The two dams on the Elwha River also have impacted the estuary and eelgrass beds.

b) Re-distribution of flows from Green (to Ship Canal and Puyallup)

Many larger freshwater networks in Puget Sound have experienced moderate to substantial re-distribution of water flow. Such "re-plumbing" of networks has resulted in significant changes to these systems, as well as to associated marine nearshore regions such as estuaries and deltas. See Section 6.8 for a specific example (e.g., re-distribution of flows within the Green/Duwamish River drainage).

Effects on salmon functions; effects on bull trout

Before 1900, more than 4,000 acres of tidal marshes and mudflats once existed where Harbor Island and the East and West Waterways currently stand (King County, 2002). As a result this estuarine habitat has been lost to salmon, and the processes that supply water (in-channel, seeps, groundwater recharge) and sediments to the Puget Sound nearshore, altered. It should be noted however, that juvenile salmonids such as anadromous salmon continue to use available habitats within the estuary, irrespective of the current condition (Von Saunder – abstract from PERS 2004 conference)



Source: King County DNR - WRIA 9 Near Term Action Agenda (2002), after Dunne and Dietrich 1978.

Figure 4-6. Re-distribution of flow in the Duwamish River drainage; prior to 1900 and after 1916.

Table 4-2 Effects of alteration of flows on ecosystems and salmon and bull trout functions

Activities	Effects on nearshore and marine ecosystem processes and habitats	Hypothesized effects on salmon and bull trout functions
Dams	• Reduced frequency of flood flows • Reduced sediment input to estuaries • Temperature and salinity fluctuations	• Reduced delta rearing habitat • Impaired physiological transition
Diversions	• Altered hydrology • Altered sedimentation • Temperature and salinity fluctuations	• Reduced habitat diversity • Altered adult migration pathways • Impaired physiological transition
Channelization	• Increased flow rates • Loss of sediment to deep water • Changes in salinity	• Physical barriers to migration • Loss of rearing habitat • Impaired physiological transition
Re-plumbing of streams and river networks	• Altered salinity profile within estuaries • Changes in delta sedimentation	• Altered or lost historic migration pathways and associated chemical signals
Forestry Activities	• Altered hydrology • Increase in fine sedimentation • Loss of large woody debris recruitment • Temperature increases	• Increased physiological stress • Loss of rearing habitat complexity over time
Development of lands	• Altered hydrology • Increased toxic and nutrient loading leading to eutrophication and hypoxia • Increased fine sediment delivery to estuary • Temperature increase	• Possible lethal and sub-lethal toxic effects • Physiological stress or even mortality in the case of hypoxia

4.4 Modification of shorelines by armoring, overwater structures, and loss of riparian vegetation

Stressor: Modification of shorelines

Examples of *activities* contributing to this stressor:

- Shoreline modifications such as armoring (e.g., by bulkheads, seawalls, groins) to protect property and/or infrastructure (e.g., railroad and road grades);
- Construction of over-water structures (e.g., docks, piers, buildings); and
- Removal of riparian vegetation (e.g., to development [residential, industrial, commercial, roads, railroads], logging, facilitate construction, provide water

views and access, accommodate landscaping) and removal of large woody debris (vessel navigation, fish passage).

Working Hypotheses

1. Armoring of shorelines to protect properties from erosion, constructing overwater structures, and removing riparian vegetation can adversely affect the ability of shoreline habitats to provide food and refuge for salmon.
2. These types of shoreline alterations, which can accompany the development of shoreline properties, affect how sediment, energy, and organic matter move within nearshore areas. Changes in these processes can lead to altered habitat characteristics, which can, in turn, reduce production of prey items for juvenile and adult Chinook and chum salmon and diminish the refuge provided to outmigrant juvenile salmon.
3. Overwater structures affect nearshore habitats by reducing light and organic matter input, altering wave action and sediment transport processes, and adding toxic contaminants. By altering these processes, overwater structures can reduce primary and secondary productivity (via increased shading and reduce organic matter input) and alter sediment characteristics (via altered wave action and sediment transport).
4. Loss or removal of riparian vegetation in the nearshore and estuarine environment alters organic matter and light input, hydrology, and sediment processes, which reduces the delivery of organic matter (affects the detritus cycle), decreases shading (increase in water temperature), and affects water quality via flow alteration and sedimentation. The effects on habitat include a loss or reduction of shoreline vegetation, organic matter, food resources, detritus cycling, large woody debris structure and function, and groundwater. Expected results include an increase in water temperatures, reduced bank stabilization, and altered organic inputs, including the delivery of terrestrial insects to the nearshore, an important food source for juvenile salmon.

Numerous scientific studies have demonstrated the importance of shorelines and nearshore regions to outmigrating Chinook and chum salmon juveniles during early life stages (e.g., see citations in reviews by Aitken 1998; Simenstad *et al*. 1999; Toft *et al*. 2004; K. Fresh, NOAA-Fisheries, personal communication; Weitkamp *et al*. 2000; Haas *et al.* 2002; Duffy 2003). Shorelines and nearshore regions are also important to anadromous bull trout for foraging, growth, migration, and overwintering (USFWS 2004).

Effects on processes and habitats

a) Shoreline Armoring

Thirty-three percent of Puget Sound shorelines have been modified with bulkheads or other types of armoring and half of this amount is associated with single-family residences (PSWQAT 2002a). For the entire state of Washington nearly one half of all shoreline modification is associated with single-family residences (PSWQAT 2002a).

Much of the sediment comprising beaches in Puget Sound results from erosion of coastal feeder bluffs, not sediment delivered by rivers (Macdonald 1995). Armoring to protect shorelines from erosion can adversely affect sediment delivery, sediment transport, and wave energy, all of which determine beach sediment composition (type, abundance and size). A number of authors have discussed the physical effects of shoreline armoring. Macdonald *et al.* 1994 (NOAA Fisheries unpublished annotated bibliography) reports that armoring can lead to the loss of beach area, narrowing of beaches, and lowering of beach profiles. Johannessen (2002) reports that armoring, such as by hard bulkheads, reduces the sediment delivered from bluffs, decreases beach area and bluffs, and decreases backshore vegetation.

Furthermore, shoreline armoring via bulkheads has been shown to deflect waves without dissipating energy (Johannessen 2002; Sobocinski *et al*. 2003), which promotes beach scour and concentrates wave energy to adjacent beaches and backshore areas (Johannessen 2002). Depending on placement of shoreline armoring structures, Macdonald (1995) reported increased turbulence and erosional energy.

Johannessen (2002) showed that bulkheads can increase sediment size on affected beaches, presumably as a result of altered sediment availability and wave energy. Sobocinski *et al*. (2003) found similar results – generally coarser sediments at altered beach sites – in a comparison of altered and natural beaches in central Puget Sound. Others have noted that armoring can contribute to "accelerated erosion of adjacent, unarmored property" (People for Puget Sound 1997).

Lastly, shoreline armoring can alter the input of organic matter to nearshore and estuarine environments. The loss of backshore vegetation and large woody debris adjacent to shorelines are but two effects of shoreline armoring specifically affecting contribution of organic matter (Shreffler *et al*. 1995; People for Puget Sound 1997; Sobocinski *et al*. 2003). In addition, armoring can disconnect aquatic and terrestrial habitats because they can effectively separate riparian and backshore areas from the aquatic environment (K. Fresh, NOAA-Fisheries, personal communication).

In many estuaries and lower reaches of rivers, bank armoring has affected bull trout by degrading and simplifying aquatic habitat, prevented channel migration, altered off-channel habitats, and degraded riparian vegetation (USFWS 2004). Railways and other road networks have contributed to the filling of estuarine habitat and degradation of nearshore habitat (USFWS 2004).

b) Overwater Structures

Overwater structures are one of the more common modifications in the nearshore and can impact intertidal habitats in the nearshore in varying ways. Shading, reduced benthic vegetation, disturbance during pier or dock construction, an increase in re-suspended sediments and turbidity from boat traffic, a change in macrofaunal assemblage, and propeller wash from boat traffic are some of the factors that have the potential to alter the nearshore environment (Haas et. al., 2002). A loss of shallow nearshore land and a change in shoreline slope are also potential impacts. These structures alter important habitat controlling factors such as light, wave energy and substrate (Nightingale and Simenstad 2001). Analysis of Washington DNR's ShoreZone inventory (Nearshore Habitat Program 2001) of information on nearshore resources indicates thousands of overwater structures were present in Puget Sound in the late 1990s to 2000, including 3,500 piers or docks, 29,000 small boat slips, and 700 large ship slips.

Eelgrass habitats are important components of estuarine ecosystems, providing spawning substrate for forage fish such as Pacific herring and critical habitat for numerous epibenthic crustaceans, all of which are important prey species for juvenile salmon (Fresh et al., 1995; Nightingale and Simenstad 2001; Haas et al., 2002) and bull trout (USFWS 2004). Small overwater structures (e.g., single family residence piers, docks, floats) built over eelgrass beds were evaluated by Fresh et al. (1995) to determine if eelgrass density declined underneath and immediately adjacent to several structures in south Hood Canal, San Juan Islands, Bellingham Bay, and Padilla Bay. Results suggested many structures erected over eelgrass beds negatively impacted "local eelgrass densities," with potentially significant amounts of eelgrass lost in areas with large numbers of docks (Fresh et al., 1995). Cumulative losses of eelgrass were considered more significant than losses at individual sites. A loss of eelgrass was also observed immediately adjacent to overwater structures in some areas. Shading was thought to be the major source of impact to eelgrass (Fresh et al., 1995). Gratings to allow light to penetrate through the overwater structures were investigated in this study and preliminary results suggested that impacts to eelgrass were reduced.

Large overwater structures such as ferry terminals can also impact intertidal habitats in the nearshore in varying ways (Nightingale and Simenstad 2001; Haas et al., 2002). Shading and potential impacts to eelgrass, and potential impacts to the epibenthos have been relatively well studied (Haas et al., 2002). These large overwater structures differ from smaller overwater structures due to the frequency of large vessel traffic, thus more frequent propeller wash events leading to an increase in re-suspended fine particle sediments which over time "can lead to a coarsening of the sediments underneath the terminal" (Haas et al., 2002). Scour pits around pilings, flushing of epibenthic fauna, and a reduction of benthic vegetation near terminals due to "bioturbation from sea stars as well as bivalves" are other impacts reported in studies (Haas et al., 2002). Ferry terminals and associated structures have also impacted bull trout by impacting continuity of habitats, as well as degrading nearshore habitat (USFWS 2004). In addition to ferry terminals, large cruise ships docked at Seattle ports have the potential to affect nearshore habitats. Cruise ship traffic has increased markedly since 1999, and to accommodate the increased demand the Port of Seattle added two docking locations in 2004 as well as additional days during the week when ships depart from port (Washington Dept. of Ecology, 2005).

c) Removal of riparian vegetation and large woody debris (LWD)

Analysis of Washington DNR's ShoreZone inventory (Nearshore Habitat Program 2001) indicates that riparian vegetation overhanging the intertidal zone is relatively rare in Puget Sound, occurring at only 440 of the nearly 2500 shoreline miles of Puget Sound. (We have not found a way to estimate the extent to which overhanging riparian vegetation has been lost from the shorelines of Puget Sound). Historically, in the mid-1800's, Puget Sound river bottoms contained dense forests, many of which were hardwoods (Collins et al, 2003). Early records described old-growth forests along shorelines in western Washington (Williams et al, 2001). Since then, much of these forests have been eradicated.

The functions and value of marine riparian zones are not as well known as for those in freshwater systems, however it is believed riparian vegetation serves similar purposes for any body of water they line, and marine riparian zones may provide added and unique functions (Williams et al, 2001). Some of the functions marine riparian vegetation are known or thought to provide to nearshore regions include 1) protection of water quality through pollution and sediment control, 2) wildlife habitat for many species, 3) microclimate and shade, 4) nutrient input, including LWD, and 5) bank stabilization (Williams et al, 2001). The effects of the removal of marine riparian vegetation on processes and habitats includes a shift in community structure, altered microclimate and soil chemistry, increased exposure to sun and wind, and the possibility of an increase in competitive interactions (Williams et al, 2001). For example, removal of riparian vegetation can lead to an increase in contaminants reaching the water (e.g., pesticides and fertilizers) as well as an increase in sediments and nutrients, all of which can lead to eutrophication (William et al, 2001). The removal of riparian vegetation can affect the microclimate due to increased exposure to various elements. This can lead to increased temperatures, increased runoff, decreased moisture, and soil desiccation or erosion (Williams et al, 2001).

Historically, Puget Sound Rivers contained dense concentration of wood, but since then much of this wood has been systematically removed from many rivers (Collins et al, 2003). For example, in five northern Puget Sound Rivers between 1880 and 1980, 150,000 snags were removed, greater than half from the Skagit River (Collins et al, 2003). In the lower Skagit River alone, 30,000 wood snags were removed between 1898 and 1908 (Collins et al, 2003).

Large woody debris and accumulations are important at multiple scales within large rivers. Wood jams can re-route water and sediment onto adjacent floodplains and deltas; wood jams can also create and maintain channels and sloughs; and wood can form pools (Collins et al, 2003). Large woody debris can be transported to the nearshore by erosion of bluffs and banks, erosion of riverbanks and transport of LWD to estuaries, as well as tidal delivery of drift logs (Williams et al, 2001). Increasing habitat complexity and heterogeneity are critical functions of LWD, "serving particularly important benefits to salmonids in estuarine marshes and nearshore environments" (Williams et al, 2001). The effect of LWD removal to processes and habitats is to reverse those processes and habitats just described.

Effects on salmon functions

a) Shoreline Armoring

When armoring changes substrate types from sand or gravel to cobble, and possibly even to hard structures (e.g., rock or hardpan), it can create conditions that provide inferior habitat for prey resources upon which juvenile Chinook and chum salmon feed (Shreffler *et al*. 1995). Thom *et al*. 1994 (NOAA Fisheries unpublished annotated bibliography) reported changes in community structure is likely a result of armoring, such as a "loss of epibenthic crustacean communities that rely on detritus when fine sediment is eroded to coarser material, or loss of bivalves and larger amphipods when coarse gravel is eroded to bedrock." Furthermore, they reported habitat for benthic species is buried or removed when beach material types are altered.

Sobocinski *et al*. (2003) suggest that the zone producing terrestrial and intertidal invertebrates that are prey for outmigrating juvenile salmon may be negatively affected by armoring as evidenced by relatively poorer invertebrate assemblages in supratidal zones affected by armoring. Thom *et al*. 1994 (NOAA Fisheries unpublished annotated bibliography) reported that food sources required by juvenile salmon such as Chinook and chum are reduced because armoring can alter the processes that transport nutrients and sediments to beaches utilized by salmon and other organisms.

Armoring can also affect prey available for adult salmon by reducing spawning habitat for intertidal-spawning finfish and degrade the quality of habitat for benthic-feeding fish (Thom *et al*. 1994, NOAA Fisheries unpublished annotated bibliography).

Toft *et al*. (2004) suggest that juvenile salmon distribution and behaviors are affected by changes in habitat characteristics (e.g., change in water depth or shoreline slope, substrate type, loss of shallow nearshore, and loss of riparian vegetation) resulting from armoring, with more readily apparent effects when shoreline modifications extended into the shallow tidal zone. Thom *et al*. 1994 (NOAA Fisheries unpublished annotated bibliography) hypothesized that habitat changes related to armoring may force fish to swim into deeper waters where they would be more susceptible to predation.

Toft *et al* (2004) suggested that relatively high juvenile salmonid densities in central Puget Sound locations with modified shorelines were an indication that the fish were forced to occupy deeper regions and form protective schools as adaptations to the habitat changes caused by shoreline modifications.

b) Overwater Structures

Simenstad *et al*. (1999) concluded that while individual over-water structures scattered along shorelines may not significantly impact salmon, the cumulative effect of dense and continuous modifications may affect salmon and salmon recovery efforts. Overwater structures alter underwater light environments, and several studies referenced in Nightingale and Simenstad (2001) document the effects of altered light conditions on juvenile salmonid physiology and behavior. Such effects can alter the behavior of migrating fish and increase the risk of mortality (Nightingale and Simenstad 2001). Studies have suggested altered underwater light conditions in Puget Sound can result in several behavioral changes, including disorientation leading to migration delays, loss of schooling in refugia (i.e., disperse rather than seek refuge in schools), and increased predation risks in deeper waters when migratory routes are altered to avoid changing light conditions (Nightingale and Simenstad 2001). In addition to increased predation risks in deeper waters, feeding capacity can be reduced (Simenstad *et al*. 1999).

Light is also critical to the abundance and distribution of seagrasses such as eelgrass. Important prey resources such as harpacticoid copepods are associated with eelgrass, and any limitation on the extent of eelgrass may impact the availability of prey resources, which can impact migration patterns and survival of juvenile fishes (Nightingale and Simenstad 2001). Prey abundance may dictate the length of residence along shorelines for fish less than 50mm (Nightingale and Simenstad 2001). Studies of small outmigrant juvenile chum salmon in Hood Canal revealed these fish feed significantly on densely concentrated copepods associated with eelgrass (Nightingale and Simenstad 2001). Those areas without eelgrass had much lower concentrations of copepods. In addition, salmon fry growth and residence time are reduced by the occurrence of overwater structures when primary and secondary production are affected; this can limit production and availability of prey (Simenstad *et al*. 1999).

c) Loss of riparian vegetation/LWD

The loss of riparian vegetation can affect salmon and bull trout in numerous ways. With the loss or removal of riparian vegetation, plant and insect food sources can be reduced, and the introduction of contaminants can lead to elevated embryo, juvenile and adult fish mortality, as well as altered growth rates and altered species or community composition (Williams et al. 2001). Shade provided by riparian vegetation is important to the spawning success of surf smelt, an obligate beach spawning species, and shading can reduce mortality attributed to desiccation and thermal stress (Williams et al. 2001). In one study, a loss of shading during summer resulted in higher surf smelt egg mortality at spawning sites as compared to mortality rates at shaded regions (Williams et al. 2001). Finally, vegetated shorelines have been shown to be important contributors of prey resources to juvenile Chinook salmon, but activities such as armoring may lead to a reduced input in these terrestrial prey resources (Brennan et al. 2004). Riparian vegetation produces organic debris that can ultimately form beach wrack, which can then attract a diversity of terrestrial insects and marine invertebrates (Williams et al. 2001). Several studies referenced in Williams et al. (2001) "identified terrestrial insects as a significant dietary component of juvenile chinook and chum salmon diets in subestuaries and other nearshore waters through Puget Sound."

LWD contributes nutrients to aquatic environments, and provides refuge, foraging opportunities, and spawning substrate for fish (Williams et al. 2001). Loss of LWD in the nearshore environment can reduce the refuge area for juvenile salmonids such as Chinook and chum salmon (Thom *et al*., 1994, NOAA Fisheries unpublished annotated bibliography).

Effects on bull trout

The primary effects of bank armoring, overwater structures, and removal of riparian vegetation and LWD on bull trout is an impact to foraging, migration, and overwintering habitat (USFWS 2004). Functional estuarine and nearshore habitats are important to anadromous bull trout, especially for foraging and migration, as well as spawning, migration, and rearing of forage fish prey species (e.g., herring, surf smelt, sand lance) important to bull trout (USFWS 2004).

Table 4-3. Effects of shoreline modification on ecosystem processes and habitats and salmon and bull trout functions

Activities	Effects on nearshore and marine ecosystem processes and habitats	Hypothesized effects on salmon and bull trout functions
Shoreline armoring	• Altered sediment and organic matter movement within the nearshore • Altered	• Altered nearshore habitat characteristics • Reduced production of prey items • Diminished refuge for juveniles
Overwater structures	• Reduced light and organic matter input • Altered wave energy regime • Altered sediment transport processes • Possible vector for toxic contaminants	• Reduced primary and secondary productivity • Potential behavioral changes • Potential exposure to contaminants
Removal of riparian vegetation/LWD	• Altered organic matter input • Increased light and temperature • Altered hydrologic and sediment transport processes • Altered groundwater delivery to the nearshore • Reduced bank stabilization	• Increased physiological stress • Reduced viability of summer spawning forage fish • Reduced terrestrial insect recruitment • Reduced refuge opportunities

4.5 Contamination of nearshore and marine resources

Stressor: Contamination due to discharges, chemicals

Examples of *activities* contributing to this stressor:
- Municipal and industrial wastewater discharges
- Stormwater discharges
- On-site sewage effluent discharges
- Oil spill, other hazardous chemical spills
- Cruise ship discharges

Working Hypotheses

1. Discharging or spilling wastes or other materials containing toxic chemicals, nutrients, and/or suspended sediments can expose salmon and bull trout and other organisms to unhealthy concentrations of contaminants and can alter the cycling of carbon and nutrients in these systems. Contamination of nearshore and marine ecosystems in Puget Sound can reduce the ability of the nearshore and marine ecosystems to provide high quality prey items for juvenile and adult Chinook and chum salmon. Altered biogeochemical cycling can diminish the refuge provided to outmigrant juvenile Chinook and chum salmon.
2. Toxic chemicals in the sediments of Puget Sound can expose salmon and other organisms to unhealthy concentrations of contaminants. Toxic contamination of nearshore and marine ecosystems in Puget Sound can reduce the ability of the nearshore and marine ecosystems to provide high quality prey items for juvenile and adult Chinook and chum salmon, and bull trout.

Numerous past and present activities contribute to the contamination of nearshore and marine resources and include, but are not limited to, wastewater discharges from industrial and municipal sources, including cruise ships; stormwater discharges; oil spills, other hazardous substance spills; and on-site sewage effluent discharges.

Nature and Extent of Threat and Impairment

Municipal and Industrial Discharges. In an investigative report published in the Seattle Post-Intelligencer, McClure *et al*. (2002) summarized municipal and industrial discharges in the Puget Sound basin as follows:

- 972 discharges are permitted by the Department of Ecology;
- 180 permit-holders had specific permission to discharge metals, including mercury and copper; and
- Over 1 million pounds of chemicals were discharged to Puget Sound in 2000 by the 20 industrial facilities that reported their releases to EPA.

These discharges originate from a great variety of facilities (e.g., almost 120 sewage treatment plants, more than 300 sand and gravel mines, five refineries) and include a variety of contaminants, including toxic contaminants and nutrients. Ecology's permits typically specify treatment requirements and many also contain limits on concentrations or total amounts of contaminants that can be discharged. Many permits require that dischargers monitor effluent and receiving waters to assess compliance with permit conditions and requirements of the Clean Water Act. McClure *et al.* (2002) noted that approximately one-third of the 8,000 permit violations reviewed by the reporters related to failure to monitor discharges as specified in a permit. Other violations discussed in this newspaper report were for discharging too much of a contaminant or too much wastewater relative to the permitted levels.

Stormwater Runoff. Runoff from urban areas of Puget Sound carries toxic contaminants and nutrients to the region's waterways, including the nearshore waters of Puget Sound. The Department of Ecology has estimated that stormwater is the cause of impairments for approximately one-third of all impaired waterbodies in Washington (cited in McClure *et al.* 2002). Toxic contaminants in stormwater include metals and hydrocarbons running off parking lots and roads and pesticides running off of landscaped areas. Nutrients in stormwater come from runoff of fertilizer and pet waste. (Note: People for Puget Sound are inventorying public stormwater discharges to marine waters and attempting to map stormwater discharges to streams and direct loadings to the marine waters)

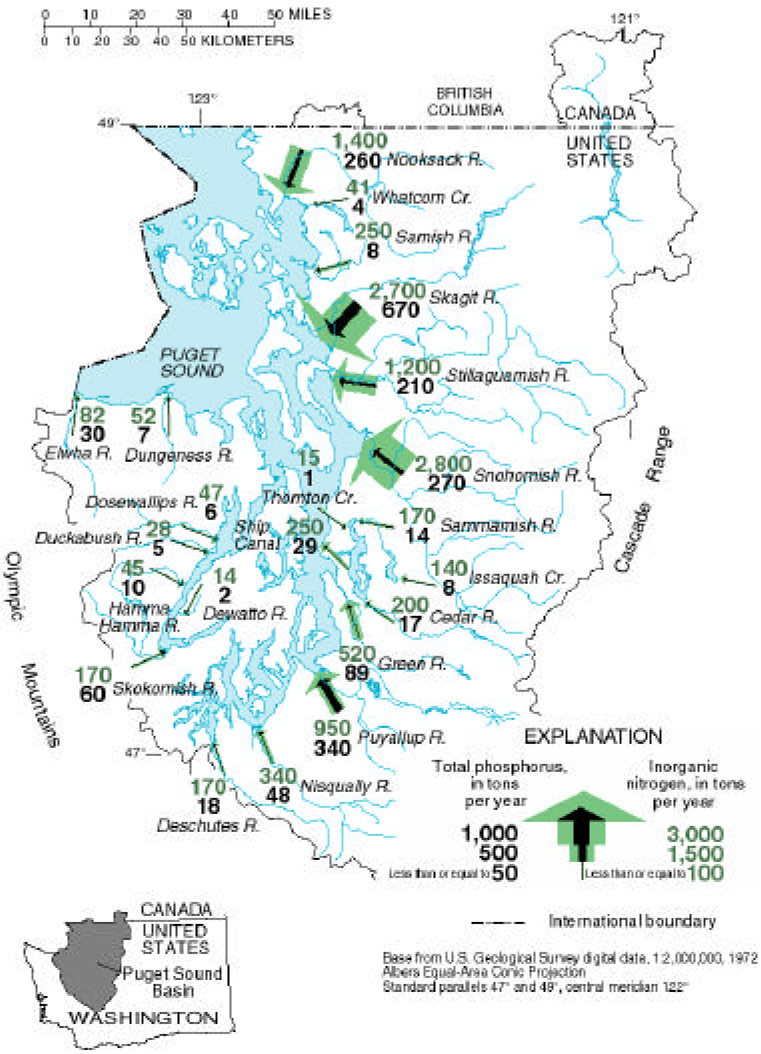
Spills. Annually, vessels transport nearly 15 billion gallons of crude oil and refined petroleum through Puget Sound (PSAT 2005). Spills of oil and other materials to the waters and land of the Puget Sound basin can introduce toxic chemicals to Puget Sound. Spills of oil in Puget Sound can also harm nearshore habitats and organisms by directly smothering shorelines. Major spills (i.e., greater than 10,000 gallons) have occurred infrequently in Puget Sound, with a total of 16 of these large spills occurring between 1985 and 2001 (PSWQAT 2002b). Smaller, but still serious, spills in which 25 to 10,000 gallons reach surface waters occur more frequently. From 1993 to 2001 there were 191 of these spills, releasing a total of more than 70,000 gallons in the Puget Sound basin (PSWQAT 2002b). The number of gallons of oil spilled has increased since 2001. In ten years (1993-2003), more than 418,500 gallons of oil have spilled in the Puget Sound basin (PSAT 2005). The most recent spills occurred in 2003 and 2004. In 2003, 4,800 gallons of bunker fuel spilled at Point Wells near Edmonds, with the winds and currents pushing the oil west to Kitsap County beaches (PSAT 2005). In 2004, nearly 1,000 gallons of oil spilled in Dalco Passage between Tacoma and Vashon Island and drifted several miles, fouling beaches, including Quartermaster Harbor (PSAT 2005).

Discharges from vessels. Cruise ships visited Seattle six times in 1999. In 2004, there were 149 port of calls in Seattle by 17 different cruise ship vessels carrying approximately 552,000 passengers (Washington Dept. of Ecology, 2005). The projected number of passengers for the 2005 season is nearly 700,000 (Washington Dept. of Ecology, 2005).

In May of 2004 in the Strait of Juan de Fuca, one cruise ship discharged approximately 16,000 gallons of sludge. Wastewater discharges from cruise ships are thought to be similar in composition to municipal wastewater (e.g., human sewage and wastewater from commercial operations such as food services and film processing) with additional discharges related to ship's operations. Cruise ships are not subject to the same treatment requirements and permits as shore-based facilities. In April 2004, an MOU between the Washington Department of Ecology, the Northwest Cruise Association, and the Port of Seattle was signed that prohibits the discharge of black and gray wastewater from cruise ships to Washington waters, except for those vessels with advanced wastewater treatment systems (Washington Dept. of Ecology, 2005). This agreement also specified that a) sludge may be discharged from a cruise ship's advanced treatment system only when more than 12 nautical miles from shore, b) a sampling regimen, with testing and reporting requirements, and c) no dumping of garbage into state waters (Washington Dept. of Ecology, 2005).

On-site sewage systems. PSAT staff estimate that there are up to 500,000 on-site sewage systems in the Puget Sound basin. The quality of effluent from these systems can vary greatly, as can the potential for nutrients or other contaminants to reach surface waters. Based on experiences with fecal contamination of Puget Sound shellfish growing areas, it is apparent that failed systems can impair water quality in local areas of Puget Sound. Loading estimates presented by Fagergren *et al*. (2004) indicate that on-site sewage systems contribute more nitrogen to Hood Canal than all other human sources combined

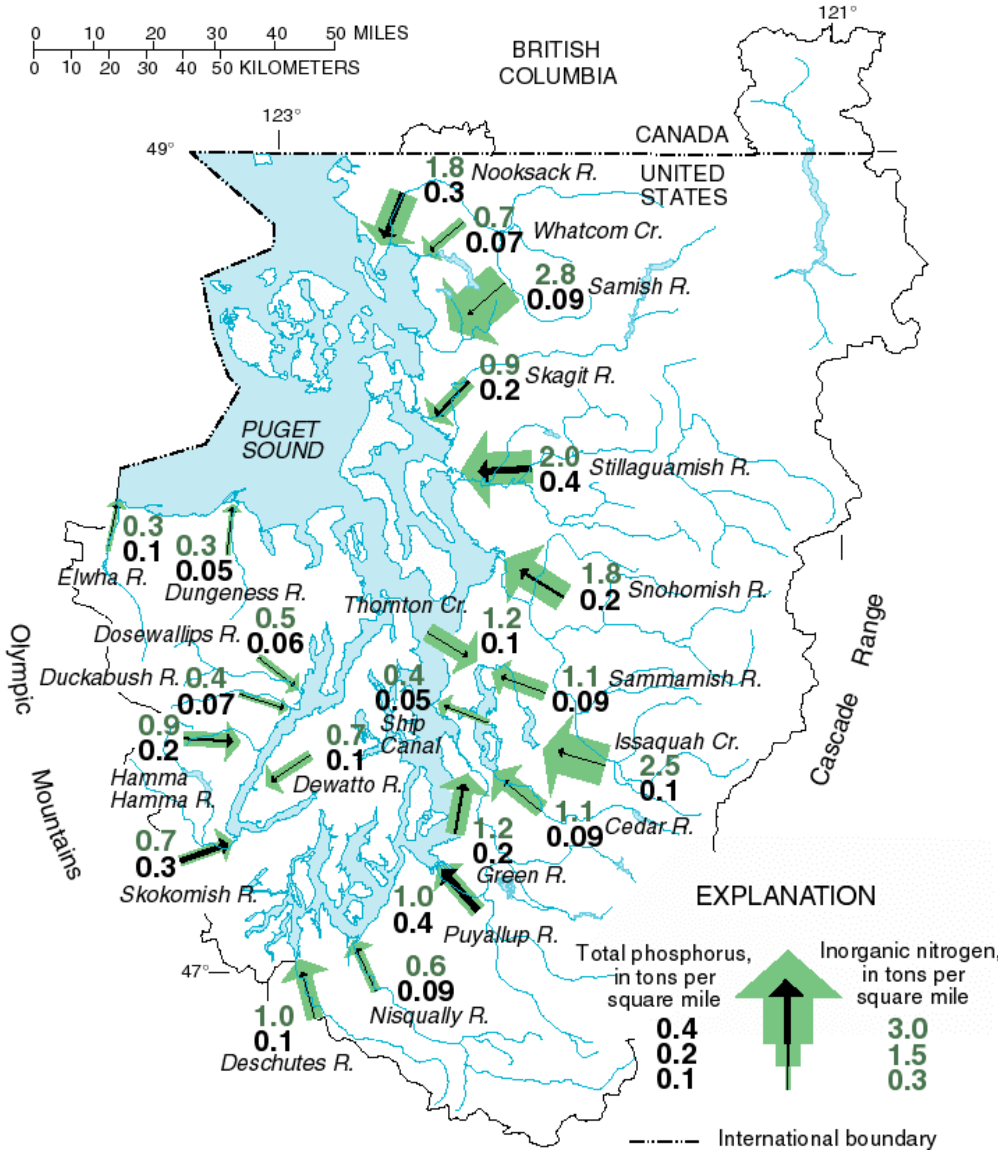
Nutrient loadings. Nutrients such as nitrogen and phosphorus can enter the Puget Sound marine environment through freshwater streams and rivers. Both nutrients are essential to sustain plant and animal life. However, excess nutrients can cause eutrophication leading to hypoxia (Fagergren et al., 2004). As part of the USGS's National Water Quality Assessment program, Embrey and Inkpen (1998) studied nutrient data from river transport to the Puget Sound Basin from 1980 to 1993. The authors reported an average annual contribution of 11,000 tons of inorganic nitrogen (9,900 tons of organic nitrogen) and 2,100 tons of total phosphorus from major rivers and streams to the Puget Sound marine environment. Major sources of nutrients entering the Puget Sound Basin via rivers and streams include animal manures, agricultural fertilizers and precipitation; wastewater treatment plants are sources of nutrients in urban areas (Embrey and Inkpen 1998). Contributions such as these are tied to land use within the Puget Sound Basin. The greatest nutrient *loads* emanate from rivers and streams exhibiting the largest watersheds and river flow (Figure 4-7). For example, the Skagit and Snohomish Rivers contribute nearly 50% of the nutrient *loads*, and with a combined drainage area of 47% of the Puget Sound Basin (Embrey and Inkpen 1998).



Source: Inkpen and Embrey (1998), USGS Fact Sheet 009-98.

Figure 4-7. Annual nutrient *loads* carried by rivers and streams to the Puget Sound Basin.

Figure 4-8 represents an adjusted picture of nutrient contributions, nutrient *yields*, which allows for the comparison of basins of different sizes. The smallest yields emanate from the Olympic Mountain watersheds and the largest yields are found in basins draining the east side of Puget Sound, with the exception of the Skagit River (Embrey and Inkpen 1998).



Source: Inkpen and Embrey (1998), USGS Fact Sheet 009-98.

Figure 4-8. Annual nutrient *yields* carried by rivers and streams to the Puget Sound Basin.

Effects on processes and habitats

Some contaminants break down at a slow rate, or not at all, and can bind to sediments where they can accumulate in plants and the tissues and organs of animals. Toxic contamination observed in Puget Sound sediments and organisms represents contributions from current discharges and historic loadings. More then 2,800 acres of Puget Sound's bottom sediments are contaminated to the extent that sediment cleanup is warranted because of concerns for toxic effects on benthic organisms (Ecology 2003). Additionally, toxic contamination is observed in the food web of Puget Sound from filter feeders (mussels) to forage fish (herring) to top predators (harbor seals) (PSAT 2002a).

The sea surface microlayer is a region that, as water levels change, various organisms can be repeatedly exposed to high levels of toxic contaminants (PSAT 2002a). The microlayer is important to the egg and larval stage of numerous organisms (PSAT 2002a), some of which may be important prey species for juvenile salmon.

Excess nitrogen loading to sensitive parts of Puget Sound (e.g., southern Hood Canal, Budd Inlet, Penn Cove)might lead to ecosystem changes (PSAT 2002a). Excess nitrogen loadings to these areas can lead to blooms of phytoplankton and subsequent reduction in dissolved oxygen in deeper waters when the blooms decompose..

Effects on salmon functions; effects on bull trout

1. Toxic contaminants from spills, discharges, and contaminated sediments

Various researchers (e.g., O'Neill *et al*. 1998 and Varanasi *et al.* 1992) have shown that Puget Sound salmon accumulate toxic contaminants during their residence in the marine and nearshore environments of Puget Sound. Effects of toxic contaminants on juvenile salmon such as Chinook and chum include: reduced immunocompetence, increased mortality after disease challenge, and reduced growth (Varanasi *et al*. 1993, Arkoosh *et al*. 1991); increased induction of hepatic cytochrome P4501A (CYP1A) and high levels of DNA damage (Stein *et al*. 1995, Varanasi *et al*. 1993); and impaired immunocompetence of juvenile Chinook salmon related to exposure to chlorinated hydrocarbons and PAHs (Arkoosh *et al*. 1994).

Varanasi *et al*, (1992) in research of toxic contaminants in sediments and in other species indicates that the food web for juvenile salmon is contaminated. Recent research from WDFW's PSAMP Fish Component has shown that toxics such as PCBs persist in the Puget Sound food web, and can be found in the tissues of Chinook salmon. It is believed sediments are a sink for legacy toxics such as PCBs, and other toxics, and the food web is a method where Chinook salmon can be exposed to toxics and subsequent accumulation in body tissues (WDFW, unpublished data).

The WDFW researchers have documented that, in general, Chinook salmon living in or migrating through Puget Sound (specifically in central and south sound) are more contaminated with PCBs than stocks outside of Puget Sound (e.g., Columbia River, WA coast). Residence time in the central and southern Puget Sound basins is suspected as a "primary predictor of PCB concentration in Chinook salmon" and as such, those salmon spending the greatest amount of time in central and south sound exhibit the greatest PCB concentrations (WDFW, unpublished data). Another toxic contaminant of concern in Puget Sound is PBDEs, a common chemical that, like PCBs, are found in greater concentrations in resident Chinook salmon versus migratory Chinook salmon. The WDFW researchers report that "this is particularly troubling as the toxic effects from PBDEs and PCBs appear to be additive."

In addition to the direct effects on salmon mentioned above, prey species such as Pacific herring have been found to be "3 to 11 times more contaminated with PCBs in central and south Puget Sound than the Strait of Georgia" (WDFW, unpublished data). These WDFW results from 2004 are similar to those reported in 1999 and 2000 in PSAT (2002a), where body burdens of PCBs were higher in Pacific herring from the central basin (Port Orchard) and southern Puget Sound basin (Squaxin Pass) than Pacific herring from northern Puget Sound and the Strait of Georgia. Finally, the WDFW researchers report that the PCB-contaminated food web of Puget Sound may explain the source of the PCBs identified in southern resident killer whales.

2. Nutrients

Excess nitrogen loading to sensitive parts of Puget Sound might lead to ecosystem changes that might affect salmon prey, refuge, and migration. Excess nitrogen loadings to sensitive areas can lead to reduction in dissolved oxygen in deeper waters, which might limit production of the food resources for juvenile and adult salmon and affect the distribution of salmon and other organisms in the water column, potentially reducing the refuge and migration functions that would otherwise be provided in these areas.

Table 4-4. Effects of contamination on ecosystems and salmon and bull trout functions

Activities	Effects on nearshore and marine ecosystem processes and habitats	Hypothesized effects on salmon and bull trout functions
Municipal and industrial wastewater discharges and cruise ship discharges	• Alters the cycling of carbon and nutrients	• Reduces production of high quality prey items • Can diminish refuge opportunities
Stormwater discharges	• Increases concentrations of metals and hydrocarbons • Increases nutrient concentrations	• Increased sub-lethal and lethal toxicity • Increases potential for hypoxia
On-site sewage effluent discharges	• Increased nutrient loading leading to eutrophication	• Increased potential for hypoxia
Oil spill, other hazardous chemical spills	• Multiple potential toxic effects to organisms and food chain through bioaccumulation	• Reduced immuno-competence • Increased mortality • Possible DNA damage

4.6 Alteration of biological populations and communities

Stressor: Alteration of biological populations, communities

Examples of *activities* contributing to this stressor:

- Hatchery releases/introductions

- Harvest
- Aquaculture (Net pens)
- Shellfish aquaculture
- Introduction of exotics

Working Hypotheses

1. Poor finfish aquaculture practices can negatively affect juvenile salmon through increased water quality degradation and introduction of diseases to wild populations.
2. The introduction of hatchery fish into Puget Sound alters biological and natural food web processes, including predator-prey relationships, impacting naturally reproducing populations in several ways. This interaction between naturally reproducing populations and hatchery salmon differs from what occurred historically in Puget Sound.
3. Increased straying rates, interbreeding and genetic effects, and peak localized numbers of fish masking true populations of wild fish have all been documented problems associated with hatcheries. The effects on juvenile Chinook and chum salmon include a reduction in available resources (via an increase in competition for food and space resources), and an increase of predation by hatchery fish on naturally reproducing populations. The resulting reduced resource base, and increased predation rates affect various life history types of many salmon populations.
4. Poor aquaculture practices can negatively affect juvenile salmon through introduction of new aquatic nuisance species and increased competition for a limited prey base in the case of escapes from salmon net pens. Roto-tilling or disking eelgrass beds for preparing clam or oyster beds by shellfish aquaculture operations can significantly alter the biological community.

Food Web Interactions

Salmon using nearshore and marine environments experience varying levels of interaction with other species. Beach seining studies conducted throughout Puget Sound list 50 to 74 fish species present in the nearshore throughout the year (Miller et al., 1977, Brennan and Higgins, 2003). In cases when beach seines are conducted during the peak of salmon migration, juvenile salmon such as Chinook and chum make up between 10 and 30 percent of the catch by number (Brennan and Higgins, 2003). Shiner perch (*Cymatogaster aggregata*) in many seining studies are by far the most abundant resident of nearshore waters (Simenstad et al, 1977, Brennan and Higgins, 2003). The relative abundance, size and diversity of species present in estuarine and nearshore waters at the time salmon co-occur will determine the level of competition for prey and likelihood of predation by larger individuals of those species.

A number of the seining studies focus on salmonids and their specific diet in the nearshore. Stomach contents of Chinook and chum salmon usually include a number of species of terrestrial and aquatic insects, crustaceans, worms and larval fish with epibenthic, neustonic and pelagic associations in the nearshore (EPA, 1991). Very little is known of the diets of other species inhabiting the nearshore at the same time as Chinook or chum juveniles. Miller, et al (1980) group Chinook juveniles in the Strait of Juan de Fuca into facultative planktivores with surf smelt (*Hypomesus pretiosus pretiosus*) and longfin smelt (*Spirinchus thaleichthys*). During a three-year study, juvenile Chinook salmon had variable diets from year to year but consistently contained drift insects. Chum juveniles are described as obligate epibenthic planktivores and share prey items with longfin smelt, Pacific tomcod (*Microgadus proximus*), walleye Pollock (*Theragra chalcogramma*), tube-snout (*Aulorhynchus flavidus*), sturgeon poacher (*Agonus acipenserinus*), shiner perch, striped seaperch (*Embiotoca lateralis*), redtail seaperch (*Amphistichus rhodoterus*) and sand sole (*Psettichthys melanostictus*) (Miller, et al, 1980).

In a south Puget Sound application of the Ecopath model, assumptions about how South Puget Sound functions differently from the rest of the basin oceanographically did not result in changes to the diet of juvenile salmon. Chinook were presumed to consume forage fish, but the importance of terrestrial insects, amphipods and copepods is consistent with other parts of the Sound (Preikshot and Beattie, 2001). Duffy reported less dependence on terrestrial insects in South Sound than North Sound based on the relative difference in freshwater inputs (Duffy, 2003). Duffy also documented that Chinook juvenile prey preferences shifted from epibenthic feeding in delta sites in April and May to planktonic and neustonic feeding in the nearshore marine sites in June and July and piscivory increased with size (Duffy, 2003).

Predation potential for juvenile Chinook and chum salmon in the nearshore is highly dependent on the size at which they enter estuarine and nearshore waters. A study of Chinook smolt predation in Salmon Bay, King County documented predation by cutthroat trout (*Oncorhynchus clarki clarki*), char and staghorn sculpin (*Leptocottus armatus*). Chinook made up 12 percent of the cutthroat diet, 34 percent was made up of other smolts, mostly chum and the remainder primarily sand lance. Char diet was 27 percent Chinook, 12 percent other salmonids and 60 percent other fish. Fifty percent of the staghorn sculpin diet was Chinook. (Footen, 2000 preliminary results)

Nature and Extent of Threats and Impairments

Hatcheries. Approximately 100 state, tribal, and federal hatcheries exist in Puget Sound and the Washington coast (Hatchery Scientific Review Group [HSRG] 2004). Figure 4-9 displays state, tribal, federal and other hatchery locations in Puget Sound. Hatchery production of Chinook salmon in Puget Sound was initiated in the late 1800s (Weitkamp *et al*. 2000) and in 1999, hatcheries released more than 88 million Pacific salmon species and steelhead into Puget Sound and Hood Canal, providing approximately 75% of the harvestable Chinook and coho salmon (HSRG 2004). In Puget Sound, the number of juvenile Chinook salmon released each year has increased from 45 ± 3 million during 1972-1983 to 53 ± 7 million during 1984-1997 (Ruggerone and Goetz 2004). Hatcheries can be production facilities where salmon are produced for tribal and non-tribal harvest, or conservation hatcheries meant to aid in salmon recovery efforts. Myers *et al* (2004)

stated that conservation hatcheries should only be temporary measures and not substitute for federal protection under the Endangered Species Act.
Harvest. Direct harvest and bycatch of Puget Sound salmon and bull trout …

Net pen aquaculture. In 2001, 10 commercial net-pen salmon farms were listed as operational in Puget Sound, totaling 131 acres under lease from state, each ranging in size from 2-24 acres (Nash 2001). Four different organizations hold leases for these net pens, and are located in several locations in Puget Sound: outside Anacortes, in Skagit Bay, Rich Passage, Port Angeles, Harstene Island, and Discovery Bay (Nash 2001). In Washington, the farming of Atlantic salmon dominates production at 99%, with the remaining facilities producing coho, Chinook and steelhead trout (Nash 2001).

Shellfish aquaculture. The Pacific Northwest oyster industry saw its beginnings in Puget Sound in the mid-1850s with the harvest of the native oyster, *Ostrea lurida*. Up to 200,000 bushels were being harvested annually from Puget Sound alone (Griffin 1997; Tillamook Bay NEP). By 1895, the stocks were seriously depleted, but the industry was revived with the introduction of the Pacific oyster, *Crassostrea gigas*, from Japan.

Effects on processes and habitats

Effects of hatcheries and harvest are discussed in the next section.

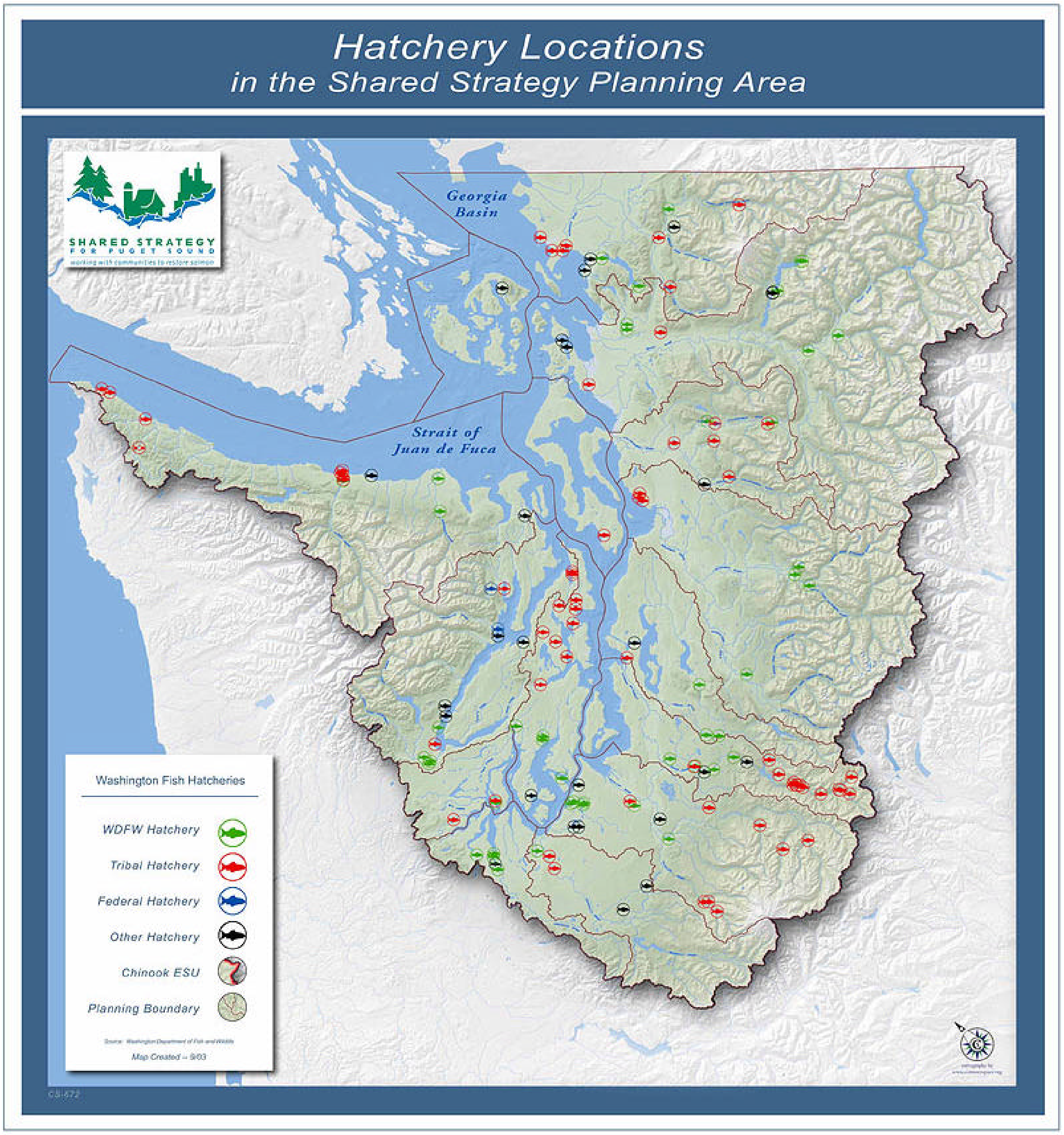
Net pen aquaculture. Fish can escape from aquaculture facilities and become an ecological problem. In the case of salmon farms, fish can escape in small numbers from "operational leakage," and in large numbers from damage to pens due to storms, human error, and so on. Examples of big escapes include an episode of 300,000 salmon escape from a Washington farm in an accident in 1997 (Center for Health and the Global Environment).

Four salmon net pens in the state of Washington in 1997 discharged 93 percent of the total amount of visible solids into Puget Sound (Center for Health and the Global Environment). Discharges from salmon farms can also contain antibiotics and other chemicals that are used to kill salmon parasites.

Shellfish aquaculture. While many attempts have been made by the aquaculture industry to minimize ecological damage from their industry and the industry actively advocates for clean water as a key business need, large-scale aquaculture, if not practiced responsibly, can have detrimental impacts to nearshore habitats.

Recent investigations suggest that commercial oyster farming has a negative impact on eelgrass meadows in Pacific Northwest estuaries.

Several studies referenced by Williams *et al*. (2001) investigating the effect of oyster culture on eelgrass beds concludes that the presence of an oyster farming operation results in decreased eelgrass abundance. These studies have documented decreased shoot density and percent cover, as well as poor natural recovery after the cessation of oyster culture in a given area. Two of the studies within Williams *et al*. (2001) investigated rack and/or stake culture, which may have very different mechanisms and effects than ground



Source: Shared Strategy for Puget Sound

Figure 4-9. State, Tribal, Federal, Other hatchery locations in Puget Sound.

culture. Other studies referenced by Williams *et al*. (2001) investigated the impact of ground culture on eelgrass, and found that ground culture causes a decrease in eelgrass abundance. One study within Williams *et al*. (2001) attributes the decline in eelgrass to dredging oysters during harvest or transplanting of the oysters, but noted a decrease in eelgrass in adjacent, non-dredged control sites as well. This study was the only study to examine dredging impacts. The other studies investigated non-dredging impacts such as shading, competition for space, erosion, and accretion.

A decrease in benthic surface area and direct physical disturbance has been cited as the probable cause of eelgrass depletion at ground culture sites. Off-bottom oyster culture, particularly rack culture, results in shading and either erosion or sedimentation that appear to be the primary cause of eelgrass depletion in those areas. Both rack and stake culture cause a decrease in eelgrass, but stake culture results in an increase in algae such as *Ulva* (sea lettuce) and *Enteromorpha.* These species in turn are suspected of having a negative effect on eelgrass (Griffin 1997; Tillamook Bay NEP).

Culturing species not indigenous to Puget Sound has resulted in a number of unintended introductions, some which have become invasive, including the three aquatic nuisance plant species mentioned below. In 2000, the Washington Department of Natural Resources organized the Puget Sound Expedition to sample Puget Sound for incidence of non-indigenous species. Out of 39 identified species, 24 were indicated to have been most likely introduced in shipments of Japanese or Atlantic oysters (PSAT 2000).

Effects on salmon functions; effects on bull trout

Hatcheries. It is now recognized that hatchery fish may pose potential negative impacts to naturally reproducing populations (i.e., wild fish) (Nehlsen et al. 1991; Aitken 1998: Weitkamp et al. 2000; HSRG 2004; Duffy 2003; Myers et al. 2004). In recent years, hatchery management practices are being reviewed because of faulty assumptions about the level of productivity of nearshore marine waters and their ability to support increasing numbers of hatchery-origin fish. Competition between wild and hatchery fish for a limited prey base became an increasing concern in some parts of the Sound.

Release of salmon from hatcheries introduces a substantial number of organisms that potentially compete with and prey on the region's wild salmon juveniles. King County documented that hatchery Chinook dominate the nearshore (54 to 75 percent of Chinook caught in beach seines) and that hatchery Chinook are larger than wild Chinook and have similar dietary preferences, which suggests a negative competitive interaction with wild fish (Brennan and Higgins, 2003). State and tribal fishery co-managers conclude in the Puget Sound Chinook Salmon Hatchery Management Plan that marine carrying capacity for Chinook may be limited and that recent year's hatchery releases from the Columbia basin exceed the historic high smolt abundance by up to 32 percent.

Myers *et al*. (2004) described brood stock from hatcheries as less adapted to survive in the wild, meaning the fish will usually exhibit poorer survival rates and altered migration and feeding behavior. Hatchery fish do not imprint to natal streams, leading to high straying rates thus distributing genetic makeup that is not locally adapted (Myers *et al*. 2004). The timing of hatchery releases can result in high localized densities, which may mask serious underlying trends in abundance (Weitkamp *et al*. 2000) and well as habitat degradation (Myers *et al*. 2004). In addition, this situation may foster increased predator populations, and with continued or increased harvest pressures, a "concomitant mortality of wild fish" (Myers *et al*. 2004; Weitkamp *et al*. 2000).

Hatchery fish are often larger in body size upon release and will compete with wild fish (Myers *et al*. 2004) for food and space resources during periods of rearing (Weitkamp *et al*. 2000). Aitken (1998) reported a great potential for competition between juvenile wild Chinook salmon and hatchery salmonids (salmon and other non-salmon species such as cutthroat) because of the juvenile wild Chinook salmon's significant dependence on estuaries in Puget Sound and elsewhere for functions such as rearing (i.e., feeding and growth). Large numbers of hatchery fish released during periods coinciding with wild fish outmigrating to Puget Sound may, if densities of hatchery fish are sufficient to deplete local food resources, affect growth of wild juvenile salmon (Duffy 2003).

Juvenile hatchery coho salmon could be a substantial predator of juvenile Chinook and chum salmon in estuarine environments if the timing of hatchery coho releases coincide with naturally reproducing populations of Chinook and chum juveniles while in estuaries (Weitkamp 2000 – draft paper). Duffy (2003) reported releases of yearling hatchery Chinook and coho salmon into Puget Sound may negatively impact naturally reproducing populations.

Harvest. Harvest effects on Puget Sound wild Chinook have been significant over the years. Harvest rates have been set without knowledge of variable ocean conditions and the genetic pressure on wild stocks from overharvesting are just now beginning to be understood.

Harvest interactions have been heavily studied by the co-managers and significant recommended changes will be forthcoming in the Chinook 4(d) rule environmental impact statement (see link below). The Puget Sound Chinook Hatchery Management Plan sets guidelines to integrate harvest and hatchery operations to meet harvest objectives, legal agreements and treaty obligations while keeping within genetic and ecological constraints such as marine carrying capacity. Refer to the following website for more information:
http://www.nwr.noaa.gov/1sustfsh/salmon/PSSalEIS/DEIS/index.html

Net pen aquaculture. Escapees from net pens can compete with and prey on native salmon and diseases and pollutants from net pens can cause infections or toxicity that might impair the marine productivity of the region's salmon and bull trout.

Shellfish aquaculture. Substrate and vegetation disruptions from ground culture of shellfish might affect food production and/or refuge for salmon and bull trout. In addition, introduction of exotic species might affect food resources.

Table 4-5. Effects of alteration of biological populations and communitities on ecosystems and salmon and bull trout functions

Activities	Effects on nearshore and marine ecosystem processes and habitats	Hypothesized effects on salmon and bull trout functions
Hatchery releases/introductions	• Altered food web processes • Increased competition for limited prey base	• Possible genetic effects • Possible disease effects • Possible increased predation
Harvest	• Altered community and food web structure • Reduced nitrogen cycling to terrestrial environment	• Genetic pressure • Reduced resistance to extreme conditions • Direct mortality
Aquaculture (net pens)	• Introduction of diseases • Introduction of non-native species • Possible increased nutrient loading contributing to eutrophication	• Increased susceptibility to disease mortality • Increased competition from escaped Atlantic salmon for breeding and rearing habitat • Potential for localized hypoxia mortality
Shellfish aquaculture	• Potential benthic habitat degradation • Introduction of exotic species	• Reduced native habitat cover

4.7 Urbanization of small marine drainages

Stressor: Transformation of land cover and hydrologic function of small marine discharges via urbanization

Examples of *activities* contributing to this stressor:

- Development (impervious surface expansion)
- Use of chemical pesticides and fertilizers
- Human sewage management

Working Hypotheses

1. The urbanization of smaller independent freshwater drainages (not connected to larger estuaries) in Puget Sound affects water quantity, water quality, and sediment composition, which affect the nearshore habitats (especially pocket estuaries and shorelines) upon which salmon depend. The effects on juvenile Chinook and chum salmon include degraded food resources; lost, degraded, or shifted refuge locations; and lost, degraded, or shifted physiological transition areas. As a result of these effects on habitat functions for salmon, urbanization of small drainages can affect the viability of fry migrants and delta fry, which might

be reliant on pocket estuaries and protected shorelines during flooding of their natal estuaries, life history types of Chinook emanating from areas affected by urbanization.

Nearly 26% of the pocket estuaries that we have identified around Puget Sound are stressed by urbanization. The "landscape function" maps presented in Appendix F illustrate the regionally-evident patterns of urban development along the low elevation streams of the Puget Sound region.

Effects on processes and habitats

Small drainages affected by urbanization experience an increase in the magnitude and frequency of floods, as well as an altered hydrologic cycle (e.g., new peak runoff events) (Figure 4-5) and deliver additional loads of contaminants and sediments to the Puget Sound nearshore (Glasoe & Christy 2004). Increased sediment loads to estuaries may lead to filled-in marsh channels and buried vegetation (K. Fresh, NOAA-Fisheries, personal communication).

Effects on salmon functions; effects on bull trout

Hydrologic alterations, sedimentation, and contamination from urbanization can affect all functions of nearshore habitats of Puget Sound for juvenile salmon. Altered hydrology can affect physiological transition. Sedimentation and contamination can affect refuge and food resources. Fragmentation of functioning habitats by the effects of urbanization can impair migratory corridors

Table 4-6 Effects of urbanization of small marine drainages on ecosystems and salmon and bull trout functions

Activities	**Effects on nearshore and marine ecosystem processes and habitats**	**Hypothesized effects on salmon and bull trout functions**
Impervious surface expansion	• Changes nearshore hydrology, temperature salinity regime • Increases toxicity and nutrient loading efficiency	• Possible sub-lethal and lethal effects • Altered physiological transition functions
Use of chemical pesticides and fertilizers	• Same as spills in Table 4-4	• Same as spills in Table 4-4
Human sewage management	• Same as on-site sewage system in Table 4-4	• Same as on-site seage system in Table 4-4

4.8 Colonization by invasive plants

Stressor: Transformation of habitat types and features via colonization by invasive plants

Examples of *activities* contributing to this stressor:

- Historical introductions
- Continued disturbance
- Nursery escapes

Working Hypotheses

1. Colonization of Puget Sound habitats by invasive plants such as *Spartina spp.*, *Sargassum muticum* and *Zostera japonica* alters natural sedimentation patterns and vegetation assemblages. These changes may reduce the ability of the affected area to provide forage, refuge functions for juvenile Chinook or chum salmon. The extent of the degradation of function is related to the level of substrate modification, the extent of the infestation, and any secondary effects like increased hypoxia or physically blocked channels.

2. Non-native plant species can out-compete native species in high salt marshes, backshore berms and coastal bluffs reducing geologic stability, altering terrestrial insect recruitment and reducing woody debris recruitment.

3. Removing native vegetation, disturbing soils, anchoring over vegetated subtidal habitats and other un-natural levels of disturbance can favor the establishment of invasive species.

Effects on processes and habitats

While over 40 aquatic nuisance species currently infest Puget Sound, *Spartina* and *Sargassum* have transformed more natural shoreline than all others. Each has aggressive growth patterns that out-compete native species. In 2003, *Spartina spp.* infested 770 solid acres of Puget Sound.

Spartina colonization begins when seeds germinate in a mud flat. The seedlings begin to grow vegetatively, forming small circular clumps called clones. These clones then coalesce into meadows, usually fringing and invading the native saltmarsh. *Spartina's* ability to fill an ecological niche in Hood Canal, devoid of predators or higher plant competition, make it capable of growing unchecked. Stout stems and root masses up to five times aboveground biomass promote accumulations of tidal sediments around *Spartina* stands. Sediment accretion takes place three times more rapidly than under normal native conditions. This results in enhanced nutrient levels for the grass clone. Altered nutrient cycles become self-perpetuating, with *Spartina* clones themselves as chief beneficiaries. This allows *Spartina* to out-compete and displace native species.

Sargassum muticum infests 18% of Puget Sound's shorelines (PSAT 2002). *Sargassum* may negatively affect water movement, light penetration, sediment accumulation and anoxia at night (Williams *et al*. 2001). *Sargassum muticum* was introduced to Puget Sound from Japan in the 1940s and patchy or continuous cover has been shown to hold and dominate space in the upper depths of *N. luetkeana* beds, in some cases preventing any re-establishment of the native assemblages that the bed originally supported. *Sargassum* does provide some of the cover structure as native kelps and it is fed upon and colonized by native species, so *Sargassum* arguably is becoming naturalized within the Sound. However, the net change in ecosystem function from the invasion of *Sargassum* is not well understood.

Zostera japonica colonizes unvegetated mudflats, competes with native eelgrass and changes the structure and diversity of the invertebrate community within the sand and mud (Williams *et al*. 2001). The invasion of *Z. japonica* has probably adversely affected the native eelgrass *Zostera marina* at the shallow water limits of distribution. The distribution of *Z. japonica* has not been well documented, but it is known to occur throughout northern Puget Sound (People for Puget Sound, 1997). *Z. japonica* can invade newly created bare patches within native *Zostera* meadows and now occupies formerly unvegetated flats, altering substantially the ecological role of these habitats. (People for Puget Sound, 1997)

Scotch Broom, *Cytisus scoparius,* and Himalayan blackberry *Rubus armeniacus,* are ubiquitous invaders of the lowlands of Puget Sound and is quite prevalent on exposed sandy bluffs, especially where shallow slides expose bare soil. These plants and several other species escaped from nursery culture and produce seeds prolifically or spread by vigorous rhizome growth. Many areas where native vegetation was removed by clearing and soil was disturbed by grading are now infested with these garden escapes to the exclusion of native shoreline species. (Levings, C. and G. Jamieson. 2001), (Manashe, E. 1993).

Non-native submerged plants like Eurasian water milfoil *Myriophyllum spicatum* and emergent plants like purple loosestrife *Lythrum salicaria* while freshwater species, may infest the upper intertidal freshwater marshes within deltas and their adjacent floodplains and within pocket estuaries. These species have the potential to hamper restoration efforts and their ecological effect or specific effects on salmon are not well understood.

Many invasive terrestrial plant species quickly outcompete native plant species for light and soil nutrients thus have the ecological effect of blocking native plant seedling establishment and natural succession. At the time of introduction, many species' potential to become invasive is unknown and it may take years for a newly introduced species to become invasive. Nurseries and garden centers do not always have up to date information on the potential of any plant to become invasive. (Washington Department of Ecology Non-native Freshwater plants website, 2003)

Effects on salmon functions; effects on bull trout

Tidal plant species supplanted by *Spartina* include two eelgrass species (*Zostera marina* and *Z. japonica*) and macroalgae. Loss of mudflat, eelgrass, and macroalgae negatively impacts those fish species that depend on these areas for feeding, spawning, or rearing habitats. Numerous studies have shown that mudflats and eelgrass can be important habitats to juvenile Chinook and chum salmon when rearing in estuarine environments (Thom *et al*. 1989; Aitken 1998; Grette *et al*. 2000; Weitkamp 2000; and Nightingale and Simenstad 2001). Also, one of the most important fixed carbon sources within estuaries, diatom populations, decline dramatically in the dense shade produced by *Spartina*. Declining populations of diatoms could negatively impacts plankton-feeding salmonids such as sockeye salmon (*Oncorhynchus nerka*). (Washington Dept. of Agriculture, 2000)

In the marine riparian area, replacement of native species with invasives may reduce the amount of shade available to beaches affecting forage fish mortality. (Penttila, D. E. 2000)

Table 4-7 Effects of colonization by invasive species on ecosystems and salmon and bull trout functions

Activities	**Effects on nearshore and marine ecosystem processes and habitats**	**Hypothesized effects on salmon and bull trout functions**
Historic introductions via aquaculture or erosion control	• Altered community structure • Altered sedimentation regime • Competition with native plant species • Potential to accelerate eutrophication	• Altered feeding and refuge opportunities • Potential mortality from hypoxia
Continued disturbance	• Expanded range of invasion • Replacement of native species with invasives in marine riparian zone may prevent shade tree development	• Reduced access to heavily invaded areas • Increased physiological stress • Reduced terrestrial insect prey
Nursery escapes	• Potential new invasions	• Unknown

4.9 Key Uncertainties and Data Gaps

This section presents an initial list of key uncertainties and data gaps relevant to effects of threats and impairments on salmon and bull trout in nearshore and marine environments.

A synopsis produced by Anne Shaffer (WDFW) from the *Salmon in the Nearshore* session of the Pacific Estuarine Research Society (PERS) Annual Meeting in 2004 identified the following data gaps relevant to sections 4.1 through 4.8: comprehensive nearshore sediment quality and toxicity; and hatchery monitoring and, specifically, consistent marking of all hatchery fish.

Disucssions with our technical advisors (Kurt Fresh and Bill Graeber) suggested the following additional data gaps relevant to this section:

- The processes by which natural and human perturbations affect nearshore ecosystems and salmon functions;
- Identify historic pocket estuary distribution across the Puget Sound landscape and learn about Chinook spawning in these systems
- Continued research in the relationship between toxic chemicals (e.g., PCBs, PBDEs), legacy sediment contamination and the food web, spatial distribution in Puget Sound, and how this affects Chinook salmon while in the Puget Sound basins;
- Studies on the effects of habitat alteration from aquatic nuisance species;
- Aggregate ecological indicator scoring approach (much like what was done for Bainbridge Island). Drift cell overlay with a host of physical and chemical stressors.
- More research to better understand the historical nutrient template with respect to salmon's importance as a marine nutrient pathway in freshwater and nearshore habitats.

4.10 Assessment Of Existing Management Actions

A number of existing state, local and federal programs can contribute to recovery of salmon populations by protecting and restoring nearshore and marine environments. This section provides a brief introduction to a number of these management programs.[1]

4.10.1 Comprehensive conservation and management for Puget Sound

Puget Sound is an estuary in the National Estuary Program and, as such, is subject to more detailed management than other coastal areas through a comprehensive conservation and management plan (CCMP). The CCMP for Puget Sound is the Puget Sound Water Quality Management Plan, amended most recently in 2000 by the Puget Sound Action Team, a broad partnership of entities involved in protecting and restoring Puget Sound and whose membership includes executives of key state and federal agencies. The goal statement for the Plan's Marine and Freshwater Habitat protection program is:

[1] This is by no means an exhaustive treatment of the management actions currently in place in the Puget Sound basin. We have focused on authorities for management actions by state and regional entities. We have not included summaries of incentive and/or education programs in this section. Such programs exist and are effective in contributing to protection by encouraging desired behaviors, investments, etc. but we have not had a chance to prepare summaries for this document. When this document is integrated with local chapters into the full regional recovery plan, we expect that a more complete depiction of existing management will be portrayed.

> *To preserve, restore and enhance the ecological processes that create and maintain marine and freshwater habitats and to achieve a net gain in ecological function and area of those habitats within the Puget Sound basin.* – Puget Sound Water Quality Management Plan adopted December 14, 2000.

This goal statement acknowledges the historic loss of marine and freshwater habitats throughout the basin and adopts the prevailing wisdom of achieving restoration of habitats by addressing the underlying processes that create and maintain them. In the first few years of implementation, this philosophy has worked its way into the lexicon of some of the region's permitting programs and is reflected in recent guidance documents such as the Shoreline Guidelines rule promulgated by Ecology for updating Shoreline Master Programs and the watershed and nearshore guidance documents for Shared Strategy.

4.10.2 Shoreline Management Act (SMA)

Implemented by local governments and subject to state Department of Ecology approval, the SMA requires all local governments to update their Shoreline Master Programs (SMPs) consistent with Ecology's new shoreline guidelines. Local SMPs contain policies, regulations, and permitting and compliance provisions addressing all shoreline use and development activities. The guidelines establish a new standard for local SMPs that requires use of the latest scientific and technical information to demonstrate that new shoreline growth and development will result in "no net loss of shoreline ecological functions". Local governments receive state funding and must base their updated SMP policies and regulations on a comprehensive inventory and assessment of shoreline ecological processes and functions, cumulative impacts and a restoration plan for shorelines that currently have degraded or impaired functions. Additional guidelines provisions establish minimum standards for all types of over water structures and shoreline modifications (reducing the number and extent of impacts from new breakwaters, jetties, groins, and bulkheads, piers and docks, dredging and fill), wetlands, vegetative buffers and structural setbacks, new residential subdivisions adnd mining activities, again, all aimed at achieving no net loss of shoreline ecological functions.

All local governments fronting on marine and Puget Sound waters are subject to SMA requirements. Therefore, the SMA provides an important tool for protecting and restoring the near shore and marine habitat upon which salmon depend.

4.10.3 Hydraulic Code

Pursuant to the Hydraulic Code, the Department of Fish and Wildlife issues Hydraulic Project Approvals (HPAs) for shoreline construction that would affect the bed or flow of a waterbody. The aim of the permit program is to protect fish life. Individual Fish and Wildlife biologists generally negotiate project designs, construction methods and timing to minimize the impacts to fish within the permit area. While the department asserts that no net loss of habitat function is achieved for each permit, the hydraulics code does not specifically address the landscape perspective of nearshore processes so lot by lot mitigation requirements are generally not adequate to prevent further degradation. Further, the Hydraulic Code RCW 77.55 allows single-family residences on marine beachfronts to locate bulkheads up to 6 feet waterward of the ordinary high water line. While the same section of the code prevents permanent loss of critical food fish or shellfish habitats, the effect on forage fish, which spawn in the upper intertidal zone may be severe over time as more waterfront properties become developed applying this maximum allowance.

4.10.4 Growth Management Act (GMA)

Implemented by local comprehensive plans, critical areas ordinances, natural resource designations and development regulations are created, maintained, updated and enforced by each local government jurisdiction and under the direction of the state's Department of Communities, Trade and Economic Development (CTED). GMA critical areas ordinances are being updated over the next two years and are required to include best available science for protecting those areas with special emphasis on anadromous salmonids. Action Team staff and partner agencies are currently involved with Puget Sound counties to result in stronger nearshore protections through this process. Best available science, including studies cited in this and other Shared Strategy documents, proceedings related to the Puget Sound Nearshore Ecosystem Restoration Project and other sources are forming the basis of these reviews and updates.

4.10.5 Aquatic Lands Act

The Department of Natural Resources (DNR) manages approximately 2 million acres of aquatic lands in Puget Sound consisting of tidelands, shore lands and bedlands on behalf of the citizens of the state. The lands are managed to provide a balance of public benefits that are varied and include encouraging direct public use and access, fostering water-dependent uses, ensuring environmental protection and utilizing renewable resources. Generating revenue consistent with the above benefits is also a public benefit. The DNR has several programs that provide management opportunities for salmon recovery in the nearshore and marine waters:

- Management of leases and easements for use of aquatic lands – each lease or easement can be conditioned to address specific environmental issues. DNR can withdraw specific aquatic lands from being available for leasing.
- Aquatic Reserves Program – DNR has developed an Aquatic Reserve Program that will ensure environmental protection of the unique habitat features at sites nominated by external entities, reviewed by a technical advisory group, and final review by the Commissioner of Public Lands.
- The DNR in partnership with The Nature Conservancy has initiated a new conservation leasing program.
- Currently, an assessment of how DNR's proprietary actions affect species that are protected by the Endangered Species Act is currently underway which will lead to the development of a Habitat Conservation Plan.
- Establishment of Aquatic Reserves – the DNR can withdraw an area from leasing and designate it as an aquatic reserve to protect unique habitat features.

- The DNR has the lead on monitoring seagrass in Puget Sound through the Puget Sound Ambient Monitoring Program and is partnering with the University of Washington in monitoring biotic communities on tidelands in south and central Puget Sound.
- The DNR is funding aquatic lands restoration projects.

4.10.6 Corps of Engineers permits under the Clean Water Act and Rivers and Harbors Act

These permits, since they are federal actions, are subject to consultation with NOAA and US Fish and Wildlife Service for any impacts to ESA listed species. Like the local and state permits, however, they are considered on an individual project basis and avoidance, minimization and compensatory mitigation do not consider the landscape context, protecting natural processes or additive impacts.

4.10.7 National Pollutant Discharge Elimination System (NPDES) permits

These federal permits for discharges to surface waters are in most cases delegated to the state Department of Ecology. The monitoring and reporting requirements of each permit are performed by the permittee (self-reporting). These permits cover discharges of municipal and industrial wastewater and stormwater. The strategy for this program is to slowly reduce the effect of overall loading of wastewater through 5-year reviews of each permit based on the initial year the permit was granted. In many cases, however, increased volumes and toxicity of discharges have been allowed in successive phases. These permits are subject to increased restrictions if ambient water quality monitoring reveals that certain pollutant constituents are exceeded within the receiving waterbody.

4.10.8 Other regulatory programs

There are a number of other programs that aim to protect against stressors discussed in this section. This subsection addresses two such programs: spills prevention and response and dredged materials management

Spill prevention programs were recently augmented by stationing a rescue tug at Neah Bay designed to respond to vessels that lose power while approaching port. However, the entire spill response network should be improved to prevent and respond to any oil, chemical or other spills that would affect salmon VSP.

Dredged material management programs require testing and avoidance of contaminated sediments that could be re-suspended by dredging and mapping of any new hot spots.

4.10.9 Acquisition and restoration programs

Protection of important features of Puget Sound's shoreline began shortly after 1964 under the State's Land and Water Conservation Fund (LWCF) Bond Program.

Established by citizen Initiative 215 in 1964, the Interagency Committee for Outdoor Recreation (IAC) helps finance recreation and conservation projects throughout the state. Both state and federal wildlife agencies have purchased nearshore habitat lands as wildlife management areas. The Nisqually, Dungeness and San Juan Islands National Wildlife Refuges and the Fir Island State Wildlife Management Area are notable nearshore acquisitions that protect thousands of acres of diverse habitat types and their associated species.

Additional state funding programs for conservation include the Washington Wildlife Conservation Fund (WWCF), Aquatic Lands Enhancement Account (ALEA), and Salmon Recovery Funding Board. These are combined with a number of federal grant sources such as North American Waterfowl Conservation Act (NAWCA) grants and Coastal Wetland Planning, Protection and Restoration Act (CWPPRA) grants administered by the US Fish and Wildlife Service. These government-funding sources are matched with local contributions to purchase lands along the nearshore, associated wetlands, low elevation riparian areas and uplands that protect nearshore habitats.

The rate of acquisition for conservation purposes by these partners has varied throughout the years and is largely dependent on the size of appropriations and availability of properties for sale. From 2000 to 2003, the rate of nearshore habitat acquisition has been approximately 3,200 acres per year (PSAT 2003). The general trend has been that properties containing shorelines and other aquatic habitats in rural areas are less expensive and more available than those same types of properties in developed areas. As population increases throughout the basin, competition between conservation and development is expected to increase. It is expected that within the next 50 years, most of the available undeveloped waterfront property will either be conserved through acquisition or restrictive covenant or developed.

Many of the funding sources and programs listed for nearshore acquisition above are also meant for restoration. Over the same time period, restoration projects such as dike breaches in estuarine marshes, levee set backs along lowland floodplains and riparian corridor reestablishment averaged approximately 1,200 acres per year (PSAT 2003).

4.10.10 Programs to restore and enhance ecological processes that create and maintain nearshore habitats

The historic, extensive losses of nearshore habitat around Puget Sound coupled with the potential for continued loss and degradation from present day and future human land uses around Puget Sound place a heavy burden on restoration just to keep pace with population growth, let alone make progress as required by the Puget Sound Management Plan. The breadth of forces degrading nearshore habitat can be remediated through restoration of one kind or another.

Restoring estuarine wetlands will increase filtering and storing low levels of diffuse pollutants such as toxic contaminants, bacteria and nutrients. Annual growth, death and transport of intertidal plants will bolster the detritus-based food web. Nearshore eelgrass and kelp beds and other shallow water areas when positioned correctly on the landscape can provide the food production, protection from predation, and migratory corridors critical for the juvenile life history stages of hundreds of marine and anadromous species, including salmon. Remediation of toxic or other pollutant hot spots will allow natural biogeochemical processes to cleanse water, sediments and eventually even organism tissues throughout the sound.

The geographic scale, scope and pace of restoration efforts will vary from one region of the Sound to another. It is unlikely that perfect pollution control permitting programs will be developed and all future loss or degradation of nearshore habitat can be avoided. Therefore, restoration must be planned to address cumulative impacts. While it is difficult to predict a rate of acquisition in the future, we can at least assume that some level of appropriation of the current funding programs will continue.

5. RECOVERY HYPOTHESES

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We have developed recovery hypotheses to express our conclusions about the key factors and uncertainties that affect the viability of salmon and bull trout through their interactions with nearshore and marine environments of Puget Sound.[1] These hypotheses synthesize the material presented in sections 2 through 4 and, hence, are based on a significant body of knowledge.

Many of these hypotheses guide the evaluation of marine sub-basins of Puget Sound that we present in Section 6. These hypotheses, and the results of the sub-basin evaluations, provide the basis for the recovery strategies presented in Section 7.

In addition to a succinct statement of our hypotheses, we also discuss the basis (e.g., empirical studies in the region, empirical studies from elsewhere, conceptual understandings) for the hypotheses and our evaluation of the certainty and risks involved in each of these statements. For some hypotheses we also provide an elaboration of the simple hypotheses statement.

5.1 Hypotheses about nearshore and marine processes and habitats [S7]

1. Movement of sediment, water, and organic matter and ecological interactions (e.g., nutrient cycling, trophic transfers, and community succession) are the key ecosystem processes at the regional scale of analysis

   Basis: Conceptual discussions by Goetz et al. (2004), Simenstad (2000), and Bauer and Ralph (1999) offer distinct but consistent arguments for addressing this suite of processes in restoration and assessment. Simenstad (personal communication with K. Fresh), Beechie et al. (2003) and Bauer and Ralph (1999) describe hierarchical interactions of processes at this scale with processes operating at different scales.

   Certainty: Moderate. Conceptual basis introduces some uncertainty (i.e., this hypothesis has not been tested and may not be testable) but various authors are in general agreement.

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[1] Although we have not organized our presentation in this way, we have developed hypotheses to address the two types of questions suggested in parts A and B of Section 3.3.2.1 of the TRT's guidance for integrated recovery planning (TRT & Shared Strategy Staff Group, 2003). These questions, interpreted for application to nearshore and marine environments, ask about:

- Effects of Puget Sound nearshore and marine ecosystems on the demographic, genetic, and ecological processes that determine the current and future viability of salmon and bull trout populations; and
- Mechanisms through which habitat management actions affect habitat-forming processes and the conditions of nearshore and marine ecosystems and the functions of these ecosystems for salmon and bull trout.

Risks: Adopting this hypothesis risks neglect of other potentially important processes such as climate variation and volcanism (which operate at larger scales) and biogeochemical processing across benthic-pelagic systems (which operates at smaller scales). This hypothesis is fundamental to our approach to the chapter (as discussed in Section 2.1) and likely limits the scope of other hypotheses and the focus of subsequent strategies and actions.

2. Spatial and temporal variations in landscape processes create a dynamic mosaic of conditions in nearshore and marine ecosystems.

   Basis: Shipman et. al (in prep) cites evidence of variation in many types of geomorphological processes (e.g., exposure, tidal range) directly from Puget Sound shorelines. Beechie et al. (2003) assert that "spatial and temporal variations in landscape processes create a dynamic mosaic of habitat condition in a river network" (and cite two works as examples that support this assertion).

   Certainty: High. Direct evidence from Puget Sound shorelines, and people's direct experiences with variations across the landscape, suggests very little uncertainty in this hypothesis. Beechie et al. (2003) make the assertion cited above as one of two factors that provide the scientific basis for their approach to recovery assessments.

   Risks: Adopting this hypothesis introduces little risk to our assessments and conclusions. This hypothesis may lead us to a more detailed analytical approach than would be necessary if processes operate uniformly over the Puget Sound landscape.

5.2 Hypotheses about effects of nearshore and marine environments on salmon

We offer the following hypotheses about how nearshore and marine environments can directly and significantly affect the viability of salmon and bull trout. Inherent in the statements below is the assumption that nearshore and marine environments can affect various units of salmon organization: individual fish, various life history strategies, populations, and ESUs or DPSs.

3. Use of nearshore and marine habitats by salmon and bull trout depends on species, life history type, and fish size

   Basis: Section 3c describes differences across species (with citations to Healy 1982 and Simenstad et al. 1982), populations (with citations to "a wide body of literature that demonstrates that habitat use depends on population of origin"), and life history strategy (with citations for Chinook to "a considerable number of studies"). The discussion in Sections 3c and 3e also addresses differences in habitat use by Chinook of different sizes.

Certainty: High. There is a considerable body of work (cited in Section 3) that informs this hypothesis.

Risks: Adopting this hypothesis introduces little risk to our assessments and conclusions. This hypothesis may lead us to a more detailed analytical approach than would be necessary if habitat use did not vary across species, populations, etc.

4. <u>Viability of salmon ESUs and anadromous portions of bull trout DPSs demands natal estuaries, nearshore areas adjacent to natal estuaries, and a diversity and connectivity of more distant nearshore habitats to provide food, refuge, conditions to support physiological transition, and passable migratory corridors.</u>

   4.1 Natal estuaries are especially important for Chinook of the delta fry outmigation trajectory but must function for all salmon and anadromous bull trout.
   4.2 Nearshore areas adjacent to natal estuaries are especially important to small, weakly swimming fish, such as Chinook of the fry migrant trajectory and outmigrant chum, but must also support larger fish.

Basis: Simenstad et al. (1982) and Simenstad and Cordell (2000) introduce the concept of four functions for salmon in nearshore environments.[S8] Section 3e offers considerable detail, including empirical evidence, about how various life histories and species use natal and non-natal estuaries and other nearshore and marine environments. Simenstad (2000) and Simenstad (2000a) argue conceptually for the importance of connectivity of habitat elements. Beechie et al. (2003) argue from the (conceptual) scientific basis of their approach to recovery that "salmonid species or populations are adapted to spatially and temporally variable habitats [and that] environmental variability is important to the long-term survival of populations." The argument that population viability specifically demands functioning natal estuaries and adjacent nearshore environments is developed as a synthesis of the material presented in Section 3 of this document.

Certainty: Moderate-to-low. There is a considerable body of work (cited above and in Section 3) that informs and supports some elements of this hypothesis. However, the overall hypothesis is relatively uncertain because there is no empirical evidence, or directly applicable conceptual discussion in the literature, about the specific relationships between population viability and conditions of various elements of the nearshore and marine landscape.

Risks: Adopting this hypothesis, and using it to define strategies and actions, risks misdirection of attention and resources from habitats that might later be shown to better contribute to salmon and bull trout viability. For example, future model results might indicate that Chinook ESU viability is substantially affected by nearshore resources very distant from natal estuaries (e.g., in Admiralty Inlet) or is not measurably affected by any nearshore conditions.

5. Viability of the Puget Sound Chinook ESU demands functioning nearshore and marine habitats in all sub-basins (to maintain or enhance nearshore and marine aspects of spatial structure) and a distribution of functions within sub-basins to support expression of each of the four outmigration trajectories in each of the five regions of diversity and risk.

   Basis: This hypothesis derives from a conceptual argument, with some basis in limited empirical evidence of the distribution of marked juvenile salmon in various Puget Sound locations, developed in Section 3 of this document. This hypothesis is a regional nearshore and marine application of the NOAA Fishery concepts of spatial structure and diversity as key elements of population and ESU viability.

   Certainty: Low. The significance of various levels of spatial structure in nearshore and marine environments and various expressions of outmigration trajectories to viability of salmon populations and ESUs is conceptually straightforward but not addressed in the literature outside this document.

   Risks: Adopting this hypothesis, and using it to define strategies and actions, risks misdirection of attention and resources from types of spatial structure and life history diversity that might have greater effects on Chinook salmon viability. For example, future model results might indicate that Chinook ESU viability is (a) affected by spatial diversity of spawning locations but not (significantly) affected by the spatial distribution of areas supporting nearshore rearing or (b) not responsive to efforts to maintain or enhance parr and yearling migrant survival in Hood Canal.

6. Realized function, which combines an assessment of opportunity and capacity, can be used as a synthetic measure of a landscape's support for salmon and bull trout populations

   Basis: Simenstad (2000) and Simenstad and Cordell (2000) introduce the concept of realized function as the product of opportunity and capacity.

   Certainty: Moderate-to-low. This hypothesis is relatively uncertain because there is no empirical evidence and very limited discussion in the literature.

   Risks: Adopting this hypothesis introduces little risk to our assessments and conclusions. One possible risk is that reliance on the assessments of opportunity and capacity could lead us to neglect some of the specific functions. However, this risk seems remote since other hypotheses and our analytical approach retain some attention to four functions of nearshore and marine habitats for salmon and bull trout.

5.3 Hypotheses about human interactions with nearshore and marine ecosystems as an influence on the viability of salmon and bull trout

7. Stressors affect four functions for juvenile salmon; the effects of these stressors vary by location and by stressor

   Basis: Sections 4.2 to 4.8 include discussion of (a) the effects of individual stressors on nearshore and marine habitat functions for salmon (with numerous citations to empirical evidence and/or conceptual arguments) and (b) the general distribution of each stressor across the Puget Sound landscape (with citations to others' characterizations of the various stressors).

   Certainty: Moderate. The nature of effects of stressors on functions for salmon are fairly well substantiated. Quantitative relationships between stressors and functions (or stressors and population or ESU viability) are not developed.

   Risks: Adopting this hypothesis introduces little risk to our assessments and conclusions. This hypothesis may lead us to a more detailed analytical approach than would be necessary if effects of stressors were uniform or if their distribution across the Puget Sound landscape were uniform.

8. Protection and restoration of nearshore and marine ecosystems to maintain or enhance realized function should address underlying ecosystem processes

   Basis: Conceptual argument developed by Puget Sound TRT and Shared Strategy Staff Group (2003). (See especially Box 2 and accompanying text in the TRT Technical Guidance for Watershed Groups.)

   Certainty: High.

   Risks: Adopting this hypothesis is intended to reduce uncertainty in recovery and does not introduce significant risks to our assessments or conclusions. However, because process-based restoration and protection are not well established in all management regimes and may not be well understood by sponsoring organizations, process-based actions and strategies might be questioned as indirect solutions to the specific problems confronting salmon and bull trout.

6. SUB-BASIN EVALUATIONS

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To systematically identify specific actions and classes of actions to advance our recovery strategies, we evaluated salmon use and ecological and landscape conditions in 11 distinct sub-basins of Puget Sound. In these evaluations, we combined the general information presented in Sections 2 through 4 and the hypotheses articulated in Section 5 with geographically specific information on salmon and the landscape in each of the sub-basins to develop recommendations for recovery strategies and actions in each sub-basin. The process of evaluation for each sub-basin included:

- assessment of salmon and bull trout use;
- assessment of ecological and landscape conditions;
- evaluation of realized function for salmon and bull trout (a combination of the capacity of habitats to support fish and the opportunities available for fish to access these habitats);
- identification of fish specific goals; and
- development of recommendations of key protection and improvement actions.

Salmon and Bull Trout Use. Our assessments of Chinook salmon use describe how juvenile, and to a lesser degree subadult and adult, chinook from the 22 independent populations delineated by the TRT are thought to occur in and use nearshore and marine environments in each of the sub-basins. Where information exists, salmon use by Chinook emanating from outside Puget Sound (e.g., Columbia River) is mentioned. The assessment of use by juvenile Hood Canal/Eastern Strait of Juan de Fuca summer chum and sub-adult and adult bull trout is discussed, but addressed in less detail. These assessments are based on the fish distribution and use hypotheses presented in Section 3 and other available location-specific information. The assessments focus primarily on salmon and bull trout in nearshore ecosystems because we know more about nearshore use than we do offshore habitat use.

Ecological and Landscape Condition. Our assessments of ecological and landscape condition focus on nearshore environments and characterize the current distribution and condition of landscapes, ecological features, and threats and stressors for each sub-basin. We characterized the distribution and condition of the landscape classes and ecological features introduced in Section 2 using information sources identified in Table 6-1 and evaluations of pocket estuaries and drift cells as described in Appendices B and C, respectively.

Evaluation of Sub-basins. The evaluation of each sub-basin includes three main pieces. First, we discuss the level of realized function for each of four life history types of outmigrant juvenile Chinook, outmigrant Hood Canal/Eastern Strait of Juan de Fuca summer chum, and bull trout. Second, we list fish specific goals. Third, we propose recovery actions to protect or improve the conditions that support these various types of fish.

The level of realized function is an aggregate measure of the availability, quality, and quantity of habitats to support salmon consistent with the recovery hypotheses presented in Section 5. Our

Table 6-1: Information Sources for Sub-Basin Assessments

Salmon and Bull Trout Use, Ecosystem Feature, Landscape Class, Stressor or Threat	Source of Information for Sub-Basin Assessment
Juvenile and adult Chinook use, chum use, bull trout use	Technical advisors, NOAA-TRT comments; USFWS (2004) Draft Recovery Plan for the Coastal-PugetSound Distinct Population Segment of Bull Trout (*Salvelinus confluentus*). Volumes I (Puget Sound Management Unit, 389 + xvii pp.) and II (Olympic Peninsula Management Unit, 277 + xvi pp.).
Forage fish: critical areas (mostly spawning beaches)	Ruggerone and Goetz , CJFAS (2004); WDFW Fish and Wildlife Science, Online Science Magazine (Bargman 2001); MRC/NW Straits (2005) Assessment of Shoreline Spawning Habitats in the Northwest Straits (2001-2004) (for location of spawn beaches)
Miles of shoreline, shoreline armoring, eelgrass, kelp, marine riparian cover, railroads, overwater structures (included docked cruise ships), exotic plant species.	Nearshore Habitat Program. 2001. The Washington State ShoreZone Inventory. Washington State Department of Natural Resources, Olympia, WA. (Abbreviated below as ShoreZone, 2001); Washington DOT (railroads); Washington DOE Digital Coastal Atlas; Washington DOE cruise ship report (2005)
1. Sub-basin delineation 2. Area of nearshore (below MHHW), area of offshore, total area	1. See in Section 2 2. CommEn Space and PSAT GIS analysis based on bathymetry (Finlayson 2005) and ShoreZone (2001)
Location and character of pocket estuaries	See Appendix B
Location and character of major drift cells	See Appendix C
Identification of bays	PSAT staff judgment
Estuaries of major rivers (11 natal estuaries for Puget Sound Chinook salmon)	PSAT GIS analysis (See Appendix A)
Development and delineation of 5- and 10-mile buffers around natal deltas	CommEn Space and PSAT GIS analysis based on the 5- and 10-mile criteria suggested by Kurt Fresh, NOAA-NWFSC (see discussion about fry migrant use of non-natal estuaries in Section 3)
Land Cover	U.S. Geological Survey (USGS) Publication Date: 19990631 Title: Washington Land Cover Data Set Edition: 1
Loss and simplification of estuarine wetlands	Bortleson et al. (1980); Collins et al. (2003)
Alteration of flow through major rivers	Bull trout recovery plan (USFWS 2004)

Salmon and Bull Trout Use, Ecosystem Feature, Landscape Class, Stressor or Threat	Source of Information for Sub-Basin Assessment
Urbanization of small drainages (for only those drainages to pocket estuaries)	Pocket estuary analysis - see Tables in Appendix E.
Discharges: 1. Municipal and industrial 2. Stormwater 3. On-site sewage 4. Cruise ship wastewater	Not specifically addressed.
Spills (oil, chemicals, other)	Identification of industrial lands along marine shorelines from land use map
Toxic contaminants 1. Sediment sites 2. Water Column	1. Sediment contamination from 2002 Puget Sound Update (PSAT 2002a). 2. Where possible - WDFW/NOAA fish contaminant monitoring data (2004)
Finfish aquaculture operations (hatcheries, net pens)	Shared Strategy map of hatchery locations; NOAA technical report (NASH 2001)
Chinook, summer chum, bull trout occurrence (if possible, utilization) in freshwater streams other than rivers entering 11 natal estuaries	Salmon and Steelhead Analysis Inventory and Analysis Program (SSHIAP), WDFW.

discussion of realized function is more qualitative than quantitative and allows identification of the features most critical for a given life history strategy or species and the features that support the greatest number of species and life history strategies.

The fish specific goals reflect our and our advisors' professional judgments based on the sub-basin assessments and the evaluation of realized function. Our recommendations of key protection and improvement actions reflect our and our advisors' professional judgments about reasonable approaches to acting on these most critical features.

As recommended by the NOAA-TRT, the material in the 11 sub-basin evaluations is organized and presented to allow the TRT to create recovery scenarios.

6.1 South Georgia Strait

A. Assessment

1. Salmon Use

Chinook

The TRT identified two independent populations emanating from this sub-basin:

- North Fork Nooksack
- South Fork Nooksack

a) Juvenile

- Juvenile Chinook salmon of all four life history types of the Nooksack populations, and larger juveniles from throughout Puget Sound (particularly from the Skagit River), utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor (juvenile salmon functions).
- Juvenile Chinook salmon have been shown to utilize small (and large) freshwater streams for direct rearing. The Dakota Creek – Point Roberts area is part of the geomorphic structure of the Fraser River delta that contains estuarine rearing habitats supporting natal chinook outmigrants. The area is also believed to provide significant rearing potential to juvenile Chinook emanating from rivers in other sub-basins. We hypothesize this non-natal support is especially important to the northern Puget Sound populations (i.e., see Table 3-1 for the list of northern Puget Sound populations).

b) Adult

- Adult Chinook salmon of the North Fork and South Fork Nooksack populations and from other Puget Sound populations utilize the South Georgia Strait (Kurt Fresh [NOAA-NWFSC], Bill Graeber [NOAA-TRT], pers. comm.). In addition to Dakota Creek mentioned above, Chinook salmon are documented as using the Lummi River (Figure E-1.1 in Appendix E).

- Adult salmon from far outside Puget Sound (e.g., Columbia River ESU's) are known to frequent this sub-basin (Kurt Fresh [NOAA-NWFSC], Bill Graeber [NOAA-TRT], pers. comm.).

Other Listed Species (not comprehensively reviewed or assessed for this sub-basin)

- Chum salmon: Populations of the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU do not emanate from this sub-basin. Non-natal use may occur, but it is not known for certain. This sub-basin is outside the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU
- Bull trout (anadromous): Occurs in one core area (Nooksack) in this sub-basin. The core area contains an estimated 10 local populations, fewer than 1000 adults (estimated) and an unknown population trend (numbers generally low) (USFWS 2004). The Nooksack core area is critical for sustaining the distribution of the anadromous bull trout life history trait within Puget Sound.

2. Ecological and Landscape Conditions

Food Web, Ecological Conditions

In the Strait of Georgia, the peak abundance of zooplankton has shifted from the month of May (1960s and 1970s) to April (1990s), presumably due to higher temperatures (Ruggerone and Goetz, 2004). Pacific herring are one type of forage fish that prey heavily upon zooplankton (West, 1997), and herring and other small schooling fish are thought to be an important part of the diet of salmon (Bargman 2001) and bull trout (USFWS 2004). In this sub-basin, Cherry Point herring, once the largest stock in Washington with spawning grounds extending from north Bellingham Bay to the Canadian border, have declined 94% from historic levels (Bargman 2001). Suspected causes for decline are discussed below. Cherry Point herring are a spring spawning stock, different from the other herring stocks in Washington, which are winter spawning stocks (e.g., Semiahmoo Bay herring stock in this sub-basin) (Bargman 2001). Many early spawning stocks in Puget Sound have not declined as much as the Cherry Point stock (Ruggerone and Goetz, 2004).

The major 1982-1983 El Nino event is thought to have affected survival of Puget Sound Chinook since that time (Ruggerone and Goetz, 2004). In the Strait of Georgia, most pink salmon enter marine waters in April, before Chinook salmon, and during even-numbered years. Prior to the large El Nino event, Chinook experienced greater survival during even-years, but since the El Nino event of 1982-1983 survival has been reduced, and Ruggerone and Goetz (2004) have hypothesized this is due to increased competition with pink salmon for prey resources. As a result, juvenile Chinook salmon may be entering marine waters at a time of reduced prey availability (Ruggerone and Goetz, 2004). In addition, the substantial decline in spawning Cherry Point herring during the early 1980s coincides with the reduced survival of Chinook and an increase in pink salmon abundance (Ruggerone and Goetz, 2004).

Landscape Conditions

In general, shorelines within the South Georgia Strait sub-basin are open to large fetches from the southwest and are therefore susceptible to wave-dominated processes like strong nearshore drift. This part of the sound also has reduced tidal amplitude compared to points further south and so waves have the opportunity to rework sediments in a finer elevation band along the shoreline. While the waters of South Georgia Strait generally exchange well through tidal action with Pacific Ocean waters, there are several places where localized oceanographic conditions create recirculating gyres which tend to increase water residence times making those waters susceptible to eutrophication and other water quality problems. (Refer to Appendix E, Figures E-1.1 through E-1.5.)

Overall area (shown in Figure 2-3 in Section 2)

- Total area (deep-water plus nearshore) is 279,999 acres (437.5 square miles).
- Deep-water portion (marine waters landscape class) comprises 216,703 acres (338.6 square miles), or 77% of the total sub-basin area.

Nearshore area

- Nearshore portion comprises 63,295 acres (98.9 square miles), or 23% of the total sub-basin area. As part of the nearshore, the Nooksack estuary (landscape class) is a natal estuary for the independent Chinook populations listed above, comprising 43.79 square miles (44%) of the total nearshore area within this sub-basin (Figure E-1.1, Appendix E).
- Nearshore area within this sub-basin is 15% of the nearshore area of the entire Puget Sound basin.
- Contains 218 miles of shoreline (beaches landscape class).
- The "key" bays (landscape class) identified in this sub-basin are Semiahmoo Bay, Birch Bay, Lummi Bay, Bellingham Bay, and Chuckanut Bay (Figure E-1.1, Appendix E).
- Thirty-one linear miles (14%) of the shoreline is designated as marine riparian (defined as the estimated area of length overhanging the intertidal zone).
- In this sub-basin, 46% of the shoreline (101 linear miles) has eelgrass (*Zostera marina* and *Z. japonica*); may be patchy or continuous.
- In this sub-basin, 17% of the shoreline (38 linear miles) has floating kelp; may be patchy or continuous. Also in this sub-basin, 35% of the shoreline (77 linear miles) has non-floating kelp; may be patchy or continuous.

Pocket Estuary Analysis

Our visual analysis of pocket estuaries in this sub-basin revealed 14 pocket estuaries: two in Drayton Harbor, three in Birch Bay, seven within Bellingham Bay, one on Lummi Island and one on Point Roberts (Figure E-1.4, Appendix E). Among the results were:

- Freshwater sources were observed in all but two of the pocket estuaries,
- Based on the assumptions listed in Appendix B, all three of the Chinook functions (feeding, osmoregulation and refuge) were estimated to occur in 11 of the 14 pocket estuaries.
- Composite "scores" were generated for each pocket estuary based on likely Chinook functions and stressors observed during analyses. None of the pocket estuaries were estimated to be *properly functioning*. Four of the 14 were estimated to be *not properly*

functioning. The remaining pocket estuaries were recorded as *at risk* (Figure E-1.2, Appendix E).

Drift Cell Analysis

A drift cell characterization for this sub-basin is presented in Appendix E, Figure E-1.5 and subsequent text. Broad intertidal and subtidal shelves that provide shallow, vegetated patches and corridors along the shoreline are a depositional feature of soft sediments generally at the depositional portions of drift cells or at the intersection of longshore drift and deltaic processes Descriptions of littoral drift, feeder sources, deltaic processes, deposition, and recommendations for protection and restoration of longshore drift functions are presented in Appendix E. Recommendations for protection and restoration are highlighted in Tables 6-2 and 6-3.

Threats/Stressors

Loss and/or simplification of delta and delta wetlands

Comparison of historical wetland area and wetland area reported in Bortleson et al. (1980) revealed that for the Nooksack delta, the estimated area of intertidal wetlands increased from 2.59 to 3.28 square miles (increased by 0.69). In this same delta, the estimated area of subaerial wetlands increased from 1.73 to 1.77 square miles (increased by 0.04). For the Lummi delta, the estimate area of intertidal wetlands decreased from 5.40 to 5.01 square miles (decreased by 0.39). In this same delta, the estimated area of subaerial wetlands decreased from 2.24 to 0.12 square miles (decreased by 2.12). Historically, the Nooksack mainstem contained floodplain wetlands and extensive estuarine marshes, but now a less complex channel pattern exists for the upper Nooksack mainstem, due in part to levees and isolating meanders (Collins et al, 2003).

Alteration of flows through major rivers

A City of Bellingham diversion dam is located on the Middle Fork Nooksack River, but is without a reservoir and does not interrupt sediment or large woody debris movement (USFWS 2004). A formerly abandoned, but recently employed hydropower facility is located on the North Fork Nooksack River (USFWS 2004). It is not known if flows are currently altered in this drainage.

Modification of shorelines by armoring, overwater structures and loss of riparian vegetation/LWD

The projected population growth in Whatcom County between 2000-2025 is 48% (79, 822 people) (PSAT 2005). Shoreline armoring occurs along 47.1 miles (21.3%) of the shoreline (Figure E-1.3, Appendix E). Over 39 miles of shoreline are classified as 100% armored. Nearly 152 miles are classified as 0% armored. The total number of overwater structures in this sub-basin is 2,843, consisting of ramps (118), piers and docks (257), small slips (2,401) and large slips (67). These structures are observed in greater concentrations in Drayton Harbor, Birch Bay, Sandy Point, and Bellingham Bay. Within 300 feet of shore, railroads occur along 8.5 miles of shoreline, from Chuckanut north to Bellingham and sections of Bellingham Bay, and again at the northeast section of Drayton Harbor.

Contamination of nearshore and marine resources

Industrial shorelines are located in several locations of this sub-basin, including Bellingham Bay and the Cherry Point region. The Cherry Point area experiences substantial shipping and petroleum movement, which occurs in the region of herring spawning grounds (Bargman 2001). A study conducted by the University of Washington, in response to potential contamination of herring spawning grounds, revealed that at Cherry Point the herring experienced a) low hatching rates from eggs, b) smaller newly hatched larvae, and c) high rate of abnormal development (Bargman 2001). Alternative hypotheses are being investigated regarding these abnormalities at this time.

Bellingham Bay is one of three locations sampled ('historic' data set from 1989 through 1996 compared to 2000) where PAH levels increased (PSAT 2002a).

Analysis of sediment samples in randomized site locations between 1997 and 1999 showed Bellingham Bay is one of several urban locations with extensive sediment contamination: 10% of the Bellingham Bay area exceeds state sediment quality standards and 2.1% exceeds cleanup screening levels (PSAT 2002a). Impaired invertebrate communities were identified in Bellingham Bay (PSAT 2002a).

Five sewage outfalls (Figure E-1.3, Appendix E) and an unknown number of stormwater discharges are also observed in this sub-basin.

Water quality impairments in this region are indicated in Figure E-1.3 (Appendix E).

Alteration of biological populations and communities

An unknown number of hatcheries, net pen facilities, and shellfish operations are found in this sub-basin. Specific hatchery reform recommendations formulated for this region by the Hatchery Scientific Review Group are presented at:
http://www.lltk.org/pdf/HSRG_Recommendations_March_2003.pdf

Transformation of land cover and hydrologic function of small marine discharges via urbanization

Figure E-1.2, Appendix E, presents land cover information for the lands surrounding this sub-basin. Figure E-1.4, Appendix E, lists pocket estuaries and notes stressors obverved from review of oblique aerial photos. We determined that Whatcom Creek, Squalicum Creek, Birch Bay and Point Roberts pocket estuaries are not properly functioning due to urbanization impacts to juvenile salmon functions (Figure E-1.4, Appendix E). Given current development pressure, we determined that Chuckanut Creek, Padden Creek, Terrell Creek, California Creek and Dakota Creek pocket estuaries are at risk of losing functions due to urbanization.

Transformation of habitat types and features via colonization by invasive plants

Spartina spp. is not recorded in this sub-basin. However, 41% of the shoreline (90 miles) contains *Sargassum muticum*.

B. Evaluation

In this section we list goals and evaluate the level of realized function for natal and non-natal Chinook, summer chum, and bull trout. From this we then list each of the proposed protection and restoration actions for this sub-basin, and describe the benefits to natal Chinook, non-natal Chinook, and summer chum and bull trout (if any).

Goals for listed salmon and bull trout whose natal streams are in this sub-basin

a) Provide early marine support for all four life history types (fry migrants, delta fry, parr migrants, yearlings) of Nooksack Chinook salmon populations: connectivity of habitats, prey resources
b) Provide support for sub-adult and adult Chinook salmon populations who utilize habitats within this sub-basin as a migratory corridor and grazing area
c) Maintain anadromous life form of bull trout by preserving forage fish species and marine foraging areas. Provide marine support for sub-adult and adult anadromous bull trout populations as foraging, migration, and overwintering habitat
d) Provide for connectivity of habitats; also, adequate prey resources, marine foraging areas, and migratory corridors for juvenile, sub-adult and adult Chinook and bull trout

Goal for listed salmon and bull trout whose natal streams are in other sub-basins

a) Provide support for all neighboring Puget Sound populations, the Skagit River Chinook populations in particular, as well as Fraser River (Canada) populations and larger juveniles from other sub-basins.

Realized function for listed salmon and bull trout

Fry migrant Chinook – The condition of pocket estuaries within 5 and 10 miles of the Nooksack estuary (Figure E-1.2 in Appendix E) suggests that Chinook fry migrants may not be well supported unless conditions are improved through restoration. Fry migrants utilizing the two pocket estuaries within Bellingham Bay may not be supported because of poor water quality. Fry migrants that emerge as parr may experience similar disruptions to their migratory corridors as delta fry that migrate southward toward Padilla and Samish bays. Any oil spills from the industrial center of Cherry Point and Bellingham Bay are a threat to this life history type.

Delta fry Chinook – During even-numbered years, juvenile Chinook salmon of this life history type may be entering marine waters at a time of reduced prey availability due to competition with pink salmon for resources (Ruggerone and Goetz, 2004). In addition, delta fry in Bellingham Bay are likely to have a higher level of exposure to toxic contaminants than other life history types. Delta fry that emerge as parr may encounter only minor disruptions in their migratory corridor if they travel northward toward pocket estuaries in Drayton Harbor and Birch Bay but potentially more frequent and intense interruptions if they migrate southward to Padilla and Samish Bays because of a higher degree of shoreline clearing, armoring and wastewater discharges. However, the role of the extensive eelgrass bed within Padilla Bay may support migrating parr in a way that is currently not understood. The opportunity for delta fry to access intertidal areas of the Lummi delta are severely curtailed. Any oil spills from the industrial center of Cherry Point and Bellingham Bay are a threat to this life history type.

Parr migrant Chinook – During even-numbered years, juvenile Chinook salmon of this life history type may be entering marine waters at a time of reduced prey availability due to competition with pink salmon for resources (Ruggerone and Goetz, 2004). The lack of properly functioning pocket estuaries throughout the sub-basin may affect the ability of parr to effectively rear especially as the limited function will be shared with all other life history types. Parr migrants moving southward toward Padilla and Samish bays may meet some disruptions as mentioned above. Any oil spills from the industrial center of Cherry Point and Bellingham Bay are a threat to this life history type if present at the time of the spill.

Yearling Chinook – During even-numbered years, juvenile Chinook salmon of this life history type may be entering marine waters at a time of reduced prey availability due to competition with pink salmon for resources (Ruggerone and Goetz, 2004). Any reduction in capacity as a result of non-support of the three smaller life history types within this sub-basin will potentially negatively affect yearling migrants. It is expected that parr migrating northward from Padilla/ Samish bays and other sub-basins to the south may be a significant source of food for yearling migrants. Yearlings will also require access to forage fish resources within the sub-basin. Any smaller life history types affected by an oil spill from the industrial center of Cherry Point or Bellingham Bay may also affect this life history type through lower prey availability or threat of toxic contamination of the food chain.

Sub-adult and adult Chinook – We hypothesize that the survival of sub-adults and adults may be impacted by a decrease in abundance of Cherry Point herring, and in the northern part of this sub-basin, a potential for competition with pink salmon in even-numbered years for prey resources.

Listed summer chum – We hypothesize that Hood Canal/Eastern Strait of Juan de Fuca summer chum do not use this sub-basin.

Anadromous bull trout – Sub-adult and larger adult anadromous bull trout forage and migrate through nearshore and estuarine areas in and around Bellingham Bay (including Whatcom Creek, and historically Squalicum Creek), and may exploit areas further north and south of the Nooksack estuary (USFWS 2004). Prey availability, condition of prey (contamination), as well as availability, and access to productive regions are likely critical to sustaining this life history type in this sub-basin.

Table 6-2. Recommended Protection Actions for the South Georgia Strait

Protection Action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Aggressively protect areas, especially shallow water/low gradient habitats and pocket estuaries, within 5 miles of Nooksack River	Early marine support of all 4 life history types of Nooksack Chinook populations (feeding and growth, refuge, osmoregulatory, migration functions). Addresses all four VSP parameters	Support for neighboring Puget Sound populations (e.g., Skagit Chinook, larger juveniles, Fraser River populations). Functions addressed: feeding and growth, refuge, osmoregulatory, migration	
Protect small creeks, and larger creeks such as Dakota Creek.	Provides habitat diversity across the landscape and spatial structure to the Nooksack population.	Provides direct rearing utilization by juveniles from adjacent sub-basins	
Protect shorelines and marine regions used for spawning by Cherry Point herring stock.	Provides prey for larger juveniles (feeding and growth); and sub-adults	Provides prey for larger juveniles (feeding and growth); and sub-adults	Provides forage base for anadromous bull trout
Protect against catastrophic events (e.g., oil spills)	Allows for the possibility of all four juvenile functions to be realized; foraging areas, connectivity, and migration pathways for sub-adults and adults	Allows for the possibility of one or more juvenile functions to be realized; foraging areas, connectivity, and migration pathways for sub-adults and adults	Bull trout: connectivity of habitats, marine/estuarine foraging areas, prey resources
Protect from further armoring and overwater structures of any shoreline property located within green boxes 1,2,3 and 5 on the map in Figure E-1.5, Appendix E. These are important feeder sources for long, functioning drift cells within the South Georgia Strait sub-basin.	(see benefits to other Chinook)	Functioning littoral drift and sediment regime for beach maintenance and spit formation – pocket estuary and lagoon formation; forage fish spawning locations. Can address up to all four juvenile functions	Provides marine and estuarine foraging areas and prey resources
Protect functioning drift cells that support eelgrass bands and depositional features along Birch Bay and Drayton Harbor shorelines as well as Portage and Lummi Island shorelines.	Provides for feeding and growth, refuge and migration for older life history types – parr migrants and yearlings (and sub-adults?)	Provides for feeding and growth, refuge and migration for older and larger juveniles (and sub-adults)	May provide foraging locations for bull trout
Protect upland sediment sources in the rust-colored boxes 4 and 7 on the map in Figure E-1.5, Appendix E by assuring that water resources planning allows for seasonal overbank flooding which delivers sediment and wood debris to these deltas.	Provides for feeding and growth and refuge for older and larger life history types; sub-adults	Provides for feeding and growth, refuge and potentially osmoregulatory functions for juveniles; sub-adults	Provides for foraging locations and prey resources for bull trout
Removal of tide gates where beneficial and possible.	Increased area for which juveniles may exploit – up to all four functions may be satisfied.	Increased area for which juveniles may exploit – up to all four functions may be satisfied.	

Table 6-3. Recommended Improvement Actions for the South Georgia Strait

Improvement Action	**Benefit to Natal Chinook**	**Benefit to Other (non-natal) Chinook**	**Benefit to summer chum, bull trout, other fish**
Let natural processes control and accomplish reconnection of Nooksack/Lummi. Goal: create substantially more estuarine habitats. Re-creation of the Lummi River delta represents a riverine estuary restoration potential of regional significance. Could recover an increment of the 70 percent historic loss of this habitat type in a block large enough to restore ecologic processes at the regional scale. Few opportunities to restore a fully functional riverine delta exist.	Increased landscape connectivity via more estuarine habitats will benefit delta fry, especially, but also fry migrants and parr migrants (feeding and growth, refuge, osmoregulation, migration functions).	Increased landscape connectivity via more estuarine habitats will benefit larger juveniles (feeding and growth, refuge, migration functions)	Bull trout could potentially benefit from the expansion of habitat area – increased foraging opportunities, prey base.
Aggressively restore areas, especially shallow water/low gradient habitats and pocket estuaries, w/in 5 miles of Nooksack River	Early marine support of all 4 life history types of Nooksack Chinook populations (feeding and growth, refuge, osmoregulatory, migration functions). Addresses all four VSP parameters	Support for neighboring Puget Sound populations (e.g., Skagit Chinook, larger juveniles, Fraser River populations). Functions addressed: feeding and growth, refuge, osmoregulatory, migration	
Restore small creeks (and some larger creeks such as Dakota Creek)		Provides direct rearing utilization by juveniles from adjacent sub-basins	
Implement local actions that will contribute to the recovery of the Cherry Point herring spawning populations	Provides feeding and growth benefit to larger juveniles (potentially) and sub-adult and adults.	Support for neighboring Puget Sound populations (e.g., Skagit Chinook, larger juveniles, Fraser River populations) and sub-adults and adults. Functions addressed: feeding and growth	Provide for increased forage base and foraging area for bull trout.
Cap toxic sediments in Bellingham Bay; control amount of sediment reaching Bellingham Bay; address contamination concerns along industrial shoreline regions (e.g., Cherry Point).	Prevents contamination of the food web for all four life history types; sub-adults and adults. Decommission roads in watershed will limit sediment input which will benefit spawning adults	Prevents contamination of the food web for neighboring populations; sub-adults and adults	Prevents contamination of the food web for anadromous bull trout

6.2 Padilla/Samish Bay

A. Assessment

1. Salmon Use

Chinook

The TRT has identified no independent populations emanating from this sub-basin.

a) Juvenile

- Juvenile Chinook salmon from the Nooksack populations utilizes this sub-basin as a non-natal rearing area. We hypothesize fish from other non-natal populations (e.g., Skagit populations), including the Nooksack, utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor
- The three bays in this sub-basin (Padilla, Samish, and Fidalgo, Figure E-1.1 in Appendix E) are all part of the geomorphic structure of the Skagit River delta, and are likely very important rearing habitats for larger fish originating from the Nooksack River. The area also likely provides significant rearing potential to larger non-natal juvenile Chinook from other sub-basins, perhaps primarily for the northern Puget Sound populations. See Table 3-1 for the list of northern Puget Sound populations

b) Adult

- Adult Chinook salmon from non-natal populations (e.g., Nooksack, Skagit) are presumed to utilize this sub-basin. Chinook are documented to use other regions in this sub-basin, including Samish River, Colony Creek, and Indian Slough. It is presumed they also use Edison Slough. See Figure E-1.1 for the distribution.
- It is not known if adult salmon from far outside Puget Sound frequent or utilize this sub-basin

Other Listed Species (not comprehensively reviewed or assessed for this sub-basin)

- Chum salmon: Populations of the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU do not emanate from this sub-basin. Non-natal use may occur, but it is not known for certain. This sub-basin is outside the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU.
- Bull trout (anadromous): Preliminary core populations (from core areas) within the Puget Sound Management Unit of bull trout are not present in this sub-basin. However, the Samish River (and Friday Creek) provides important foraging, migration, and overwintering habitat for sub adult and adult anadromous bull trout (USFWS 2004). Several salmon species and steelhead is a forage base for anadromous bull trout. Samish River habitat is especially important to proximate bull trout populations (e.g., Nooksack, Skagit populations) (USFWS 2004).

2. Ecological and Landscape Conditions

Food Web, Ecological Conditions

Oceanographically, the Padilla/Samish sub-basin is part of the historic Skagit delta where deltaic processes are no longer active. However, the historic flow of fine sediments into Padilla Bay has created a broad, shallow basin making almost the entire bay intertidal. Padilla Bay and Samish Bay both experience reduced mixing since agricultural dikes reduced the freshwater inflow into the area. Samish Bay still has the influence of the Samish River and Edison slough freshwater and sediments. Nutrient implications for the sub-basin include potential eutrophication from agricultural sources. Forage fish (specifically Fidalgo Bay population of herring are important to salmon. Primary/secondary productivity for the system is high because of the extensive eelgrass meadow in Padilla Bay. It is expected that significant amounts of detritus is exported from Padilla Bay to neighboring San Juan Islands and South Georgia Strait sub-basins. The eelgrass also helps to support a thriving Dungeness crab fishery. Padilla Bay is designated as a National Estuarine Research Reserve and contains one of the largest eelgrass beds on the West Coast, providing habitat for many species.

Landscape Conditions

Even though these bays are shallow, significant open water fetch can create waves on the bays and move nearshore sediments along certain key features such as Samish Island and March Point. However, the western margin of this sub-basin contains rocky shorelines that are resistant to longshore drift processes and contain fringing kelp beds. See Figures E-1.1 through 1.3, E-2.4 and 2.5 for depictions of landscape conditions in this sub-basin.

Pocket Estuary Analysis

Our visual analysis of pocket estuaries in this sub-basin revealed seven pocket estuaries: four in Samish Bay and three in Padilla Bay (Figure E-2.4, Appendix E). Among the results were:

- Freshwater sources were observed in all but one of the pocket estuaries,
- Based on the assumptions listed in Appendix B, all three of the Chinook functions (feeding, osmoregulation and refuge) were estimated to occur in six of the seven pocket estuaries.
- Composite "scores" were generated for each pocket estuary based on likely Chinook functions and stressors observed during analyses. Two pocket estuaries were estimated to be *properly functioning*. One pocket estuary was estimated to be *not properly functioning*. The remaining four pocket estuaries were recorded as *at risk*.

Drift Cell Analysis

As in other sub-basins with rocky shorelines, the action of longshore sediment drift processes has reduced importance in shaping the nearshore landscape in this sub-basin. Samish Island is a notable exception. Extensive shallow mudflats that do not appear to move alongshore, but are critical deltaic features of the landscape dominate the eastern shoreline of the sub-basin.

Overall area

- Total area (deep-water plus nearshore) is 52,416 acres (81.9 square miles).
- Deep-water portion (marine waters landscape class) comprises 9,856 acres (15.4 square miles), or 19% of the total sub-basin area.

Nearshore area

- Nearshore portion comprises 42,560 acres (66.5 square miles), or 81% of the total sub-basin area. A natal estuary (landscape class) is not present in this sub-basin (Figure E-1.1).
- Nearshore area within this sub-basin is 10% of the nearshore area of the entire Puget Sound basin.
- Contains 100 miles of shoreline (beaches landscape class).
- The “key” bays (landscape class) identified in this sub-basin are Padilla Bay, Samish Bay, and Fidalgo Bay (Figure E-1.1, Appendix E).
- Ten linear miles (10%) of the shoreline is designated as marine riparian (defined as the estimated area of length overhanging the intertidal zone).
- In this sub-basin, 73% of the shoreline (73 linear miles) has eelgrass (*Zostera marina* and *Z. japonica*); may be patchy or continuous.
- In this sub-basin, 8% of the shoreline (8 linear miles) has floating kelp; may be patchy or continuous. Also in this sub-basin, 17% of the shoreline (17 linear miles) has non-floating kelp; may be patchy or continuous.

The drift cell analysis for this sub-basin is presented in Appendix E, Figure E-2.5 and subsequent text. Recommendations for protection and restoration presented in the Appendix are highlighted in Tables 6-4 and 6-5.

Threats/stressors

Loss and/or simplification of delta and delta wetlands

Comparison of historical wetland area and wetland area reported in Bortleson et al. (1980) revealed that for the Samish delta, the estimated area of subaerial wetlands decreased from 0.73 to 0.15 square miles (decreased by 0.58). The estimated loss or gain of intertidal wetlands is not available. Historically, estuarine wetlands were extensive in the Skagit-Samish delta, consuming an area more than twice that of the Nooksack, Stillaguamish and Snohomish deltas, combined (Collins et al, 2003). Diking and draining of wetlands has reduced the area. The loss of side channel regions and riparian vegetation in floodplains and estuarine areas can be attributed to such activities as agricultural practices (USFWS 2004).

Alteration of flows through major rivers

Larger-scale flow alterations are not present in this sub-basin. Smaller dams and diversions may occur.

Modification of shorelines by armoring, overwater structures and loss of riparian vegetation/LWD

Shoreline armoring occurs along 50.9 miles (51.6%) of the shoreline (Figure E-1.3, Appendix E). Over 47 miles of shoreline are classified as 100% armored. Nearly 38 miles are classified as 0% armored. The total number of overwater structures in this sub-basin is 1,868, consisting of ramps (29), piers and docks (79), small slips (1,726) and large slips (34). These structures are observed in greater concentrations in the northeast section of Fidalgo Island in the area of Anacortes. Within 300 feet of shore, railroads occur along 9.5 miles of shoreline, from near Windy Point in Samish Bay northward to Larrabee State Park, and the northeast section of Fidalgo Island.

Contamination of nearshore and marine resources

Potential contamination sources in Padilla Bay include failing septic systems, stormwater runoff, poor agricultural practices (including dairy farming), and industrial and commercial development.

Two sewage outfalls (Figure E-2.3, Appendix E) and an unknown number of stormwater discharges are also observed in this sub-basin.

Water quality impairments are indicated in Figure E-1.3, Appendix E.

Alteration of biological populations and communities

There are five fish hatcheries on or directly adjacent to this sub-basin with unknown effects on competition and community structure. Refer to the hatchery reform recommendations of the Hatchery Scientific Review Group at the following website.
http://www.lltk.org/pdf/HSRG_Recommendations_March_2003.pdf

Transformation of land cover and hydrologic function of small marine discharges via urbanization

Rural development and suburban sprawl is an increasing threat within the agricultural region of Padilla Bay (citation in Estuarine Research Federation Spring 2003 Newsletter). Fidalgo Bay and Edison Slough are among the pocket estuaries degraded by urbanization within this sub-basin (Figure E-2.4, Appendix E). See Figure E-2.4 for an evaluation of pocket estuaries and stressors noted through review of oblique aerial photos. Figure E-1.2, Appendix E, presents land cover information for the area surrounding this sub-basin.

Transformation of habitat types and features via colonization by invasive plants

In this sub-basin, 5% of the shoreline (5 miles) contains patchy or continuous *Spartina spp*. Also, 18% of the shoreline (18 miles) contains patchy or continuous *Sargassum muticum*. *Spartina alterniflora* has nearly been eradicated from Padilla Bay, but seedlings from *S. anglica* are present in adjacent bays and require annual monitoring and control (citation from Estuarine Research Federation Spring 2003 Newsletter).

B. Evaluation

In this section we list goals and evaluate the level of realized function for natal and non-natal Chinook, summer chum, and bull trout. From this we then list each of the proposed protection and restoration actions for this sub-basin, and describe the benefits to natal Chinook, non-natal Chinook, and summer chum and bull trout (if any).

Goals for listed salmon and bull trout whose natal streams are outside this sub-basin

a) Provide support for all neighboring Puget Sound populations, the Skagit River and Nooksack River Chinook salmon populations in particular
b) Provide foraging, migration and overwintering habitats for neighboring populations of bull trout.
c) Support spatial structure & diversity VSP parameters for all salmon populations

Realized function for listed salmon and bull trout

Fry migrant Chinook – Fry migrants from both the Nooksack and Skagit estuaries are likely to use this entire sub-basin, not just the pocket estuaries, as the shallow water, mudflats and eelgrass beds support similar functions as pocket estuaries (Figure E-1.2, Appendix E). The existing unarmored shorelines and three fully functioning pocket estuaries support this life history type very well. During high tides and storm events, however, all seven pocket estuaries may be needed to support refuge functions. Chemical stressors and sewage outfalls likely affect Nooksack fry migrants as they move into Samish Bay. Water quality impacts from agricultural runoff can affect this life history type throughout the sub-basin. Connectivity between Padilla Bay and the Skagit estuaries is limited for fry migrants from the Skagit and other river systems in Whidbey Basin. Spartina infestations could impact this life history type by blocking channels with sediment. Any oil spills from March Point are a threat to this life history type.

Delta fry Chinook – No delta fry life history types are expected to be present in this sub-basin unless extreme flood events transport delta fry from the Nooksack estuary to the north or the Skagit estuary to the south. In such an event, the extensive mudflat and eelgrass habitats within this sub-basin would support delta fry. Significant improvement to this function could be realized by removal of dikes fronting both Samish and Padilla Bays eastern shorelines. Spartina infestation will likely have little adverse impact to this life history type unless infestations begin to block existing channels. Any oil spills from March Point are a threat to this life history type.

Parr migrant Chinook – A diversity of habitat types exist for parr migrants in this sub-basin. Opportunity to access them for populations from the Whidbey sub-basin is constrained as mentioned above for fry migrants. Spartina infestations could affect parr migrants seeking nearshore channel structure in salt marshes. Oil spills from March Point could pose a threat to this life history type if they are present at the time of the spill.

Yearling Chinook - Any reduction in capacity as a result of non-support of the three smaller life history types within this sub-basin will negatively affect yearling migrants. It is expected that parr migrating from other sub-basins to the south and north will be a significant source of food for yearling migrants. Yearlings will also require access to forage fish resources within the sub-basin, which are considerable. Any smaller life history types affected by an oil spill from March Point will also affect this life history type through lower prey availability or threat of toxic contamination of the food chain.

Sub-adult and adult Chinook – Survival of sub-adult and adult Chinook salmon is dependent on several factors, including the production and availability of forage fish species within nearshore regions, marine vegetation such as eelgrass and kelp, and water quality. We hypothesize that during even-numbered years, Chinook salmon may experience increased competition with pink salmon for resources.

Listed summer chum – We hypothesize that Hood Canal/Eastern Strait of Juan de Fuca summer chum do not use this sub-basin.

Anadromous bull trout – Even though this sub-basin does not contain core area populations, sub-adult and adult anadromous bull trout from nearby populations utilize regions of this sub-basin as foraging, migration and overwintering habitats.

Table 6-4. Recommended protection actions for Padilla/Samish Bay

Protection Action	Benefit to Natal Chinook	Benefit to other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Aggressively protect unarmored shorelines, especially along the west shore of Padilla Bay and all shorelines of Guemes Island	N/A	Protects shallow subtidal shelves supporting vegetated migration corridors for Nooksack and Skagit migrants	
Protect Fidalgo Bay herring stock (support both staging and spawning functions in this area)	N/A	Protects feeding function for all populations migrating through this sub-basin	Protects feeding function for anadromous bull trout
Continue protections of large eelgrass meadow (2nd largest on the west coast) in Padilla Bay.	N/A	Vegetative cover for migration, feeding of Skagit and Nooksack parr migrants, yearlings	Protects feeding function for anadromous bull trout
Protect against further *Spartina* infestations.	N/A	Protects existing physiological transition, feeding and refuge functions for Skagit and Nooksack, other migrating populations	
Aggressively protect Joe Leary Slough, Indian Slough and Samish River delta estuaries	N/A	Protects existing physiological transition, feeding and refuge functions for Skagit and Nooksack, other migrating populations	Protects feeding function for anadromous bull trout

Table 6-5. Recommended improvement actions for Padilla/Samish Bay

Improvement Action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Continue to mechanically remove *Spartina* colonies	N/A	Increase native cover and feeding support for Nooksack and Skagit migrants	
Improve connections between the Skagit delta and Padilla Bay to support two-way movement of fish	N/A	Support feeding and refuge functions of the Skagit such as fry and parr outmigrants, particularly of the delta fry life history type.	Would improve access/connectivity between the Skagit delta and neighboring deltas for bull trout feeding
Remove agricultural dikes along the south shoreline of Padilla and Samish Bays where feasible	N/A	Support feeding and refuge functions of the Skagit such as fry and parr outmigrants, particularly of the delta fry life history type.	Would improve access/connectivity between the Skagit delta and neighboring deltas for bull trout feeding
Consider wastewater reclamation and reuse retrofits for Anacortes wastewater discharge	N/A	Reduced physiological stress from nutrient loading and potential eutrophication	Reduced physiological stress from nutrient loading and potential eutrophication

6.3 Eastern Strait of Juan de Fuca

A. Assessment

1. Salmon Use

Chinook

The TRT has identified two independent populations from this sub-basin:
- Elwha
- Dungeness

a) Juvenile
- Juvenile Chinook salmon of all four life history types of the Dungeness and Elwha populations utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor (juvenile salmon functions).
- Larger juvenile Chinook salmon and older life history types from non-natal populations are often found to utilize habitats and landscape features in this sub-basin. We hypothesize that Chinook from all 22 populations utilize the sub-basin's nearshore as a migratory corridor (see Table 3-1 for the list of Puget Sound populations).

b) Adult

- Sub-adult and adult salmon from Puget Sound populations utilize habitats within this sub-basin as a passage corridor and grazing area. Other than the Dungeness and Elwha, Chinook are documented to use Morse Creek and other regions in the eastern Strait (Figure E-3.1)
- Adult salmon from far outside Puget Sound (e.g., Columbia River and Snake River ESU's) may utilize habitats within this sub-basin as a passage corridor and grazing area.

Other Listed Species (not comprehensively reviewed or assessed for this sub-basin)

- Chum salmon: Two natal populations (Jimmy Comelately, Salmon/Snow) of the Hood Canal/Eastern Strait of Juan de Fuca Summer chum ESU exist in this sub-basin. We hypothesize that all populations of Hood Canal/Eastern Strait of Juan de Fuca Summer chum utilize the sub-basin's nearshore as a migratory corridor. Historically, summer chum were documented to have used Johnson's Creek.
- Bull trout (anadromous): Occurs in two core areas (Elwha, Dungeness) in this sub-basin. The Elwha core area contains one identified local population, but additional populations may exist. The status is unknown for this core area, but few individuals exist in the Elwha population (USFWS 2004). The Dungeness core area contains two populations, of unknown status. Bull trout use has also been documented in Ennis Creek, Bell Creek, Seibert Creek, and Morse Creek.

2. Ecological and Landscape Conditions

Food Web, Ecological Conditions

Shaffer and Crain (2004) summarize ecological conditions in this sub-basin as follows:

> The north Olympic Peninsula has extensive shorelines that border the Strait of Juan de Fuca and the Pacific Ocean. More than 80% of the water from Puget Sound and the Strait of Georgia flows through the Strait of Juan de Fuca (Mackas and Harrison 1997). Direction of net water movement within the Strait of Juan de Fuca depends on depth. Net movement of cold oceanic deep water is to the east while net movement of fresher, warmer surface water is to the west (Mackas and Harrison 1997; Strickland 1983).
>
> The Strait of Juan de Fuca is a wind-dominated system, with currents changing dramatically within hours in response to both regional and larger scale oceanic winds (Hickey 1996; Strickland 1983). Strong seasonal storms contribute pulses of both freshwater and sediment to the Strait of Juan de Fuca. These pulses will form large lenses of very low salinity and very high turbidity within the nearshore zone along the majority of the shoreline of the Strait of Juan de Fuca. These lenses appear to occur primarily during winter and spring months. Due to deep oceanic water and strong wind and current mixing action, as well as seasonal strong contribution of riverine nutrients, the water of the main basin is well-mixed, cold, and nutrient-rich throughout the year (Mackas and Harrison 1997). This is in direct contrast to the shallow enclosed embayments of the Strait of Juan de Fuca, which

may be seasonally stratified and, in some instances, nutrient-limited (Mackas and Harrison 1997).

The Elwha River dams and shoreline armoring are largely responsible for sediment starvation along the shoreline within the Elwha drift cell. As a result, the shorelines contain larger substrates and extensive kelp beds.

Forage fish use is highly variable, and surf smelt spawning appears to occur later in the summer than in other areas of Puget Sound, with egg mortality approaching 30% (Shaffer 2004). Forage fish spawn in lower rivers on the Olympic peninsula and have been shown to use kelp beds. Forage fish spawning habitat in the nearshore and riverine environments are extremely important.

Landscape Conditions

Shaffer and Crain (2004) describe nearshore as: "a critical component to marine ecosystems, and the nearshore Strait of Juan de Fuca is a critical component of a functioning Puget Sound ecosystem. It is the conduit for species migrating to and from inland marine waters of Puget Sound and British Columbia."

Continuity and connectivity of eelgrass and kelp beds are important to migrating juvenile and sub-adult salmon from all 22 populations of Chinook and the populations of Hood Canal/Eastern Strait of Juan de Fuca Summer chum

See Figures E-3.1 through E-3.5 in Appendix E for additional characterization of the landscape of this sub-basin.

Pocket Estuary Analysis (includes area west to Elwha River only)

We identified 22 pocket estuaries in this sub-basin: most are located at the southern terminus of Discovery Bay, Sequim Bay, Dungeness Bay and Port Angeles Harbor as seen in Figure E-3.4.

- Freshwater sources were observed in all but six of the pocket estuaries,
- Based on the assumptions listed in Appendix B, all three of the Chinook functions (feeding, osmoregulation and refuge) were estimated to occur in nine of the 22 pocket estuaries.
- Composite "scores" were generated for each pocket estuary based on likely Chinook functions and stressors observed during analyses. Seven pocket estuaries were estimated to be *properly functioning*. Eight pocket estuaries were estimated to be *not properly functioning*. The remaining pocket estuaries were recorded as *at risk*. (Fig. E-3.2)

Drift Cell Analysis

Unlike the pocket estuary analysis, drift cell function was considered for major drift cells west to Neah Bay with the Strait of Juan de Fuca. The action of wind-dominated waves on both bluff and deltaic sediments is a strong determining factor on beach structure. The Strait also provides

Overall area (pertains to that portion of the Strait west to the Elwha River; only the drift cell analysis reflects the entire strait west to Neah Bay)

- Total area (deep-water plus nearshore) is 412,030 acres (643.8 square miles), the largest of all 11 sub-basins.
- Deep-water portion (marine waters landscape class) comprises 363,390 acres (567.8 square miles), or 88% of the total sub-basin area.

Nearshore area (except for information in the first two bullets, all information pertains the entire Strait, west to Neah Bay)

- Nearshore portion comprises 48,640 acres (76 square miles), or 12% of the total sub-basin area. As part of the nearshore, the Elwha and Dungeness estuaries (landscape class) are natal estuaries for the independent Chinook populations listed above, comprising 12.75 square miles (17%) of the total nearshore area within this sub-basin. (Fig. E-3.1)
- Nearshore area within this sub-basin is 12% of the nearshore area of the entire Puget Sound basin.
- Contains 217 miles of shoreline (beaches landscape class).
- The "key" bays (landscape class) identified in this sub-basin are Discovery Bay, Sequim Bay, Freshwater Bay, Crescent Bay, Clallam Bay, and Neah Bay.(Fig. E-3.1)
- 17 linear miles (8%) of the shoreline is designated as marine riparian (defined as the estimated area of length overhanging the intertidal zone).
- In this sub-basin, 34% of the shoreline (75 linear miles) has eelgrass (*Zostera marina* and *Z. japonica*); may be patchy or continuous.
- In this sub-basin, 44% of the shoreline (95 linear miles) has floating kelp; may be patchy or continuous. Also in this sub-basin, 74% of the shoreline (161 linear miles) has non-floating kelp; may be patchy or continuous. The kelp beds of the Strait of Juan de Fuca are the majority of Washington's coastal kelp resources.

a living laboratory of large-scale drift cell function that happens over shorter time periods than elsewhere in the Sound and so intensive monitoring of sediment transport as a result of restoration actions is very feasible here. The drift cell characterization for this sub-basin is presented in Appendix E, Figure E-3.5 and subsequent text. Littoral drift, feeder sources, deltaic processes, deposition, and recommendations for protection and restoration are discussed in Appendix E and highlights of recommendations are presented in Tables 6-6 and 6-7.

Threats/stressors

Loss and/or simplification of delta and delta wetlands

Comparison of historical wetland area and wetland area reported in Bortleson et al. (1980) revealed that for the Dungeness delta, the estimated area of subaerial wetlands did not change from historical to date of survey in 1980 (0.19 square miles). The estimated area of intertidal wetlands increased slightly from 2.28 to 2.32 square miles. Since the time of the Bortleson report in 1980, the Dungeness region has experienced rapid growth, and the estuary has been altered from historic conditions by conversion to agriculture, development, and altered sediment transport regimes.

Information is not available from the Bortleson (1980) report for the Elwha delta. The Elwha estuary and wetlands have been altered since construction of two dams, discussed below. The Elwha estuary was historically not large, but the size has decreased since construction of the two dams (Wunderlich et al, 1994).

Alteration of flows through major rivers

Two dams exist on the lower Elwha River. The lowermost dam, Elwha, was constructed in 1910 and both this and the Glines Canyon dam have significantly altered the nearshore and estuary due to a loss of sediment transport. An estimated 17.7 million cubic yards of clay, silt, sand, gravel and cobbles have accumulated behind both dams, and would be released upon dam removal scheduled to begin in 2007 (Elwha River Ecosystem Restoration Implementation, Final Environmental Impact Statement, 1996).

The Dungeness River system is impacted by water withdrawals. On the lower Dungeness River floodplain, tributaries and independent drainages have been diked, levied and channelized. Diking of channels has altered the flow of water in distributary channels.

Modification of shorelines by armoring, overwater structures and loss of riparian vegetation/LWD

In this sub-basin west to the Elwha River only, shoreline armoring occurs along 37 miles (27%) of the shoreline. (Fig. E-3.3) Over 16 miles of shoreline are classified as 100% armored. Nearly 99 miles are classified as 0% armored. In this sub-basin west to Neah Bay, the total number of overwater structures is 1,439, consisting of ramps (33), piers and docks (104), small slips (1,286) and large slips (16). These structures are observed in greater concentrations in Port Angeles, Sequim Bay and Discovery Bay. The railroad no longer operates on the Olympic peninsula, but the railroad grade is still present. Within 300 feet of shore railroad grades occur along 1.8 miles of Eastern Strait shoreline, along Discovery Bay, part of Sequim Bay, and a section of the Port Angeles shoreline.

Contamination of nearshore and marine resources

Non-point pollution via nutrient loading (as well as stormwater and industrial uses) is a significant concern in this sub-basin, and when combined with shoreline alterations in semi-enclosed embayments, macroalgae blooms (e.g., *Ulvoid* mats) can occur which can elicit changes to community structure.

Water quality impairments stressors in this sub-basin are mapped in Fig. E-3.3

Alteration of biological populations and communities

Two hatcheries exist on the lower Elwha River (Wunderlich et al, 1994). Specific hatchery reform recommendations for this region have been formulated by the Hatchery Scientific Review Group available at the following website.
http://www.lltk.org/pdf/HSRG_Recommendations_February_2002.pdf

Shellfish aquaculture occurs primarily within protected bays like Dungeness Bay, Sequim Bay and Discovery Bay.

Transformation of land cover and hydrologic function of small marine drainage via urbanization

Urbanization effects hydrologic function in 7 pocket estuaries within this sub-basin including Cassalery Creek, Morse Creek, Peabody Creek and Valley Creek which provide important sources of freshwater to the nearshore. See Figure E-3.4 for a list of pocket estuaries and stressors noted by review of oblique aerial photos.

Transformation of habitat types and features via colonization by invasive plants

In this sub-basin west to Neah Bay, *Spartina spp* are not found. Also, 2.3% of the shoreline (5 miles) contains *Sargassum muticum*, which may be patchy or continuous.

B. Evaluation

In this section we list goals and evaluate the level of realized function for natal and non-natal Chinook, summer chum, and bull trout. From this we then list each of the proposed protection and restoration actions for this sub-basin, and describe the benefits to natal Chinook, non-natal Chinook, and summer chum and bull trout (if any).

Goals for listed salmon and bull trout whose natal streams are in this sub-basin

a) Provide early marine support for all four life history types (fry migrants, delta fry, parr migrants, yearlings) of Elwha and Dungeness Chinook salmon populations.
b) Provide early marine support for the two natal populations of Hood Canal/Eastern Strait of Juan de Fuca Summer chum.
c) Provide marine support for sub-adult and adult anadromous bull trout populations within the two core areas in this sub-basin (Elwha, Dungeness).
d) Provide for connectivity of habitats; also, adequate prey resources, marine foraging areas, and migratory corridors for juvenile, sub-adult and adult Chinook, juvenile chum, and bull trout.

Goal for listed salmon and bull trout whose natal streams are outside this sub-basin

a) Provide support for all neighboring Puget Sound populations (juveniles, sub-adults, and adults). All 22 populations of Chinook in Puget Sound, (and presumably all populations of Hood Canal/Eastern Strait of Juan de Fuca Summer chum) utilize nearshore and marine regions of this sub-basin as a migratory corridor.

Realized function for listed salmon and bull trout

Fry Migrant Chinook – Fry migrants from the Dungeness Chinook population are well supported by low energy shorelines, pocket estuaries and Sequim Bay although poor water quality (e.g., low dissolved oxygen, stratification) within Sequim Bay and Discovery Bay (Fig. E-3.1) could be limiting survival at some times of year due to *Ulvoid* blooms. The lack of sufficient low energy shoreline or functional pocket estuaries near the Elwha delta could be limiting support for this life history type (Fig. E-3.2). Fry migrants that use pocket estuaries near Port Angeles may be exposed to higher levels of toxic contaminants. Also, removal of the two Elwha River dams is expected to benefit this life history type.

Delta Fry Chinook – Current conditions for delta fry of the Elwha Chinook population river are diminished but expected to improve greatly as a result of new sedimentation following dam removal. Delta fry in the Dungeness are well supported. Poor water quality in semi-enclosed embayments may impact this life history type. Also, removal of the two Elwha River dams is expected to benefit this life history type.

Parr Migrant Chinook - Parr migrants emerging from Elwha and Dungeness rivers would be well supported by the diversity of habitat types along this shoreline, however, the high energy nature of much of this shoreline suggests an added importance for pocket estuaries to act as refuge. Parr migrants will also be a major food source for larger sized life history types migrating toward the ocean from Puget Sound and South Georgia Basin. Poor water quality in semi-enclosed embayments may affect this life history type. Also, removal of the two Elwha River dams is expected to benefit this life history type.

Yearlings – Yearlings will find support in this sub-basin as they are similarly sized to other migrants passing through the region. Nearshore habitat west of the Elwha River is particularly useful because of the extensive kelp beds lining the shoreline. Poor water quality in semi-enclosed embayments may affect this life history type (as discussed above). Also, removal of the two Elwha River dams is expected to benefit this life history type.

Sub-adult and adult Chinook – Survival of sub-adult and adult Chinook salmon is dependent on the production and availability of forage fish species within nearshore regions of this sub-basin. In addition, marine vegetation such as eelgrass and kelp also play an important role in salmon survival. Poor water quality in semi-enclosed embayments may impact this life history type (as discussed above). Removal of the two Elwha River dams is expected to greatly benefit returning spawners, as an additional 70 miles of river will become available for spawning. Adequate adult escapement from the Straits fishery is also important.

Summer Chum – We hypothesize that small summer chum fry from the Dungeness and Elwha populations will encounter similar conditions as discussed in the fry migrant and delta fry Chinook sections, above. Marine vegetation is especially important to chum salmon because they leave estuarine regions for nearshore waters after a short period, and require adequate food supply such as copepods, as well as refuge opportunities. Many prey species are associated with marine vegetation such as eelgrass. Poor water quality in semi-enclosed embayments may impact this life history type (as discussed above). Also, removal of the two Elwha River dams is expected to benefit summer chum.

Bull Trout – The Strait of Juan de Fuca's estuaries and nearshore waters provides critical foraging, migration, and overwintering habitats for sub-adult and adult anadromous bull trout (USFWS 2004). In this region, these habitats are important for maintaining life history diversity and access to productive foraging regions (USFWS 2004). In addition to the Elwha and Dungeness core areas, bull trout have been shown to use other marine tributaries (e.g., Ennis Cr., Bell Cr., Morse Cr., and Siebert Cr.) for foraging and overwintering, possibly as "stepping stones" when moving through marine waters, as well as refuge from high water events (USFWS 2004). Poor water quality in semi-enclosed embayments may impact this life history type (as discussed above). Also, removal of the two Elwha River dams is expected to benefit bull trout.

All life history types in this sub-basin are at risk of non-support in the event of an oil spill since large volumes of crude oil are transported through this area to refineries at March Point and Cherry Point.

Table 6-6. Recommended Protection Actions for the Eastern Strait of Juan de Fuca

Protection Action	**Benefit to Natal Chinook**	**Benefit to Other (non-natal) Chinook**	**Benefit to summer chum, bull trout, other fish**
Protect pocket estuaries and shallow water/low velocity habitats from further degradation near the deltas (w/in 5 miles), but skew this protection area to the east per oceanographic currents	Early marine support of all 4 life history types of Elwha and Dungeness Chinook populations (feeding and growth, refuge, osmoregulatory, migration functions). Addresses all four VSP parameters	Support for neighboring Puget Sound populations (e.g., Hood Canal Chinook, larger juveniles from other populations, Fraser River populations). Functions addressed: feeding and growth, refuge, osmoregulatory, migration	Support for neighboring Hood Canal summer chum, anadromous bull trout and other species. Functions addressed: feeding and growth, refuge, osmoregulatory, migration
Protect all feeder bluffs	Sustained migratory functions, riparian food source, refuge for Elwha and Dungeness populations	Sustained migratory functions, riparian food source, refuge for Hood Canal Chinook populations	Sustained migratory functions, riparian food source, refuge for Hood Canal summer chum populations; refuge, feeding and growth functions for anadromous bull trout
Protect against catastrophic events (oil spills)	Sustained feeding, growth, refuge, migration, osmoregulation for Elwha & Dungeness populations	Sustained feeding, migration and growth for Hood Canal Chinook, migration for other populations	Sustained feeding, growth, refuge, migration, osmoregulation for anadromous bull trout; feeding and migration for summer chum.

Protection Action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Protect functioning drift cells that support eelgrass bands and depositional features along the shoreline of Discovery Bay to Fort Worden (shoreline protection targets 19-23 in Fig. E-3.5), all west Whidbey Island shorelines within the sub-basin and between Port Angeles and Agnew (shoreline protection target 11).	Sustained feeding, growth and migration for Elwha and Dungeness populations	Sustained feeding, growth and migration of Hood Canal and other Puget Sound populations	Sustained feeding, growth and migration for summer chum, anadromous bull trout and other species.
Aggressively protect Eagle Creek, Paradise Cove and Bell Creek lagoon as properly functioning pocket estuaries within the sub-basin	Sustained feeding, growth, refuge and osmoregulation for Elwha and Dungeness populations	Sustained feeding and growth for Hood Canal and other populations	Sustained feeding, growth, refuge and osmoregulation for anadromous bull trout; feeding and refuge for summer chum
Protect delivery of upland sediment sources to the nearshore from Shoreline protection targets 1a,b,c, 2,5,7, 10, 12-15 and 24 in Fig. E-3.5	Sustained feeding, growth, refuge and osmoregulation functions for Elwha and Dungeness populations	Sustained feeding, refuge and migration functions for all populations	Sustained feeding, growth, osmoregulation and refuge for anadromous bull trout; feeding, migration and refuge for summer chum and other species

Table 6-7. Recommended Improvement Actions for the Eastern Strait of Juan de Fuca

Improvement Action	Benefit to natal Chinook	Benefit to other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Consider and or continue (expand) wastewater reclamation and reuse retrofits for Port Townsend, Sequim (model for success) and Port Angeles wastewater discharges	Improved feeding and growth, osmoregulation functions for Elwha and Dungeness populations		
Restore pocket estuaries and shallow water/low velocity habitats near the deltas (w/in 5 miles), but skew this protection area to the east per oceanographic currents	Improved feeding, growth, osmoregulation and refuge functions for Elwha and Dungeness populations	Improved feeding, migratory and refuge functions for Hood Canal and other populations	Improved feeding, growth, osmoregulatory and refuge functions for anadromous bull trout; feeding and refuge, and migratory functions for summer chum and other species
Incorporate beach nourishment from Port Angeles landfill to Ediz Hook (special restoration target 8) as elements of the efforts to restore the Elwha delta and adjacent shoreline	Improved migratory feeding and refuge functions for Dungeness population	Improved migratory functions for all Puget Sound populations	Improved migratory, feeding and refuge functions for anadromous bull trout; migratory functions for summer chum and other species
Consider restoration of functions in Maynard, Blyn, Glenn Creek and Morse Creek pocket estuaries currently at risk of degradation	Improved feeding, growth, refuge and osmoregulatory functions for Elwha and Dungeness populations	Improved feeding and migratory functions for other Puget Sound populations	Improved feeding, growth, osmoregulatory and refuge functions for anadromous bull trout; feeding and migratory functions for summer chum and other species
Restore estuarine delta structure and functions as a result of Elwha dams removal and re-establishment of low elevation channel migration zones (Shoreline restoration target 7). This projects is regionally significant	Improves all functions for all life history types of Elwha population. Feeding, growth osmoregulation and refuge functions for Dungeness population fry migrants	Improves feeding, migration and refuge functions for all Puget Sound populations	Improves feeding, growth, osmoregulation functions for anadromous bull trout; feeding, migratory and refuge functions for summer chum and other species

6.4 San Juan Islands

A. Assessment

1. Salmon Use

Chinook

The TRT has identified no independent populations emanating from this sub-basin.

a) Juvenile
- Juvenile Chinook salmon from multiple non-natal populations from all Geographic Regions of origin utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor (juvenile salmon functions) (See Figure 3-1 for a list of all Chinook populations).

b) Adult
- Sub-adult and adult salmon from Puget Sound populations utilize habitats within this sub-basin as a migratory corridor and foraging area.
- Adult salmon from far outside Puget Sound (e.g., Columbia River and Snake River ESU's) may utilize habitats within this sub-basin as a migratory corridor and foraging area.

Other Listed Species (not comprehensively reviewed or assessed for this sub-basin)
- Chum salmon: Populations of the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU do not emanate from this sub-basin. Non-natal use may occur, but it is not known for certain.
- Bull trout (anadromous): Preliminary core populations (from core areas) within the Puget Sound Management Unit of bull trout are not present in this sub-basin.

2. Ecological and Landscape Conditions

Food Web, Ecological Conditions

The San Juan Islands are unique in their location and as such, are an important corridor for adult fish from all populations. Forage fish and eelgrass are important components of the San Juan Islands' ecology. Forage fish require functioning nearshore habitats for spawning and rearing. Forage fish are critical prey items for salmon, as well as to marine mammals and birds.

In 2004, Friends of the San Juans produced a forage fish spawning habitat study report revealing forage fish spawning habitat regions within the archipelago. Four priority forage fish spawning habitat regions were identified: Mud/Hunter Bay region on Lopez Island; Westsound and Blind Bay Region on Orcas and Shaw islands; Mackaye Harbor Region on Lopez Island; and Greater Westcott Bay Region on San Juan Island.

Landscape Conditions

Rocky shorelines dominate the San Juan Islands therefore, there is less perceived need for armoring. Protected shorelines of inner bays may be important for forage fish spawning because that is where the appropriate sediment grain sizes settle out. Wind and waves cause large vertical zonation of intertidal flora and fauna on some shorelines within the sub-basin.

Connectivity of habitats suitable for forage fish spawning is limited so the importance of support functions for rearing forage fish may be more important than spawning habitat here. Continuity of eelgrass and kelp beds are important to migrating juvenile and sub-adult salmon from all 22 populations of Chinook and the populations of Hood Canal/Eastern Strait of Juan de Fuca Summer chum. The importance of Haro Strait and other passes between the larger San Juan Islands as corridors for migrating adult salmon indicate an importance for Southern resident orca populations that rely on adult salmon for food.

See Figures E-3.1 through 3.3, E-4.4 and 4.5 in Appendix E for information about the landscape conditions in this sub-basin

Overall area

- Total area (deep-water plus nearshore) is 181,887 acres (284.2 square miles).
- Deep-water portion (marine waters landscape class) comprises 146,175 acres (228.4 square miles), or 80% of the total sub-basin area.

Nearshore area

- Nearshore portion comprises 35,776 acres (55.9 square miles), or 20% of the total sub-basin area. A natal estuary (landscape class) is not present in this sub-basin.
- Nearshore area within this sub-basin is 8% of the nearshore area of the entire Puget Sound basin.
- Contains 387 miles of shoreline (beaches landscape class).
- Numerous smaller bays can be found in the San Juan Island complex. Some of the bays (landscape class) identified in this sub-basin are Echo Bay, East Sound, West Sound, Deer Harbor, Blind Bay, Parks Bay, Burrows Bay, Mud Bay, Hunter Bay, Aleck Bay, Shoal Bay, Swifts Bay, Fishermans Bay, North Bay, Friday Harbor, Reid Harbor, Mitchell Bay, Westcott/Garrison Bay, False Bay, Roche Harbor, and Open Bay.
- Thirty-one linear miles (8%) of the shoreline is designated as marine riparian (defined as the estimated area of length overhanging the intertidal zone).
- In this sub-basin, 43% of the shoreline (168 linear miles) has eelgrass (*Zostera marina* and *Z. japonica*); may be patchy or continuous.
- In this sub-basin, 29% of the shoreline (114 linear miles) has floating kelp; may be patchy or continuous. Also in this sub-basin, 61% of the shoreline (238 linear miles) has non-floating kelp; may be patchy or continuous.

Pocket Estuary Analysis

We identified 29 pocket estuaries in this sub-basin spread throughout many of the larger islands.

- Freshwater sources were observed in over half the pocket estuaries,
- Based on the assumptions listed in Appendix B, all three of the Chinook functions (feeding, osmoregulation and refuge) were estimated to occur in nearly all the pocket estuaries.
- Composite "scores" were generated for each pocket estuary based on likely Chinook functions and stressors observed during analyses. Sixteen pocket estuaries were estimated to be *properly functioning*. Two pocket estuaries were estimated to be *not properly functioning*. The remaining 11 pocket estuaries were recorded as *at risk*.

Drift Cell Analysis

There are many small drift cells operating on soft sediment shorelines of the San Juan Islands between rocky beach areas. Many of the soft sediment depositional features in the islands also rely on upland sediment sources being delivered from small coastal streams. The drift cell characterization for this sub-basin and is presented in Figure E-4.5 and subsequent text in Appendix E. Littoral drift, feeder sources, deltaic processes, deposition, and recommendations for protection and restoration are discussed in Appendix E and highlights of our recommendations for protection and restoration included in Tables 6-8 and 6-9.

Threats/stressors

Loss and/or simplification of delta and delta wetlands

Natal estuaries for Chinook salmon do not occur in this sub-basin. No information is presented for smaller, non-natal deltas and delta wetlands.

Alteration of flows through major rivers

Larger-scale flow alterations are not present in this sub-basin. Smaller dams and diversions likely exist but are not identified here.

Modification of shorelines by armoring, overwater structures and loss of riparian vegetation/LWD

Shoreline armoring occurs along 17 miles (4%) of the shoreline (Fig. E-3.3). Over 12 miles of shoreline are classified as 100% armored; greater than 346 miles are classified as 0% armored. The total number of overwater structures in this sub-basin is 3,642, consisting of ramps (56), piers and docks (507), small slips (3,065) and large slips (14). Railroads do not occur in this sub-basin.

Contamination of nearshore and marine resources

The nearshore and marine waters of this sub-basin are in relatively good condition compared to other regions of Puget Sound, but the potential for contamination exists. Potential non-point sources of contamination identified in the San Juan County Watershed Management Action Plan

(2000) include on-site septic systems, conversion of lands to residential and commercial development, stormwater runoff, agricultural practices, forestry practices, marinas and boating activities, and solid waste/hazardous waste. Of these, on-site septics, conversion of lands, and stormwater runoff were ranked as primary pollution sources. Location-specific pollution sources were specified in the report.

See Fig. E-3.3 in Appendix E for a depiction of water quality impairments in this sub-basin.

Alteration of biological populations and communities

Only one hatchery is found within the sub-basin and shellfish aquaculture operations are limited to small-scale oyster string culture operations in several embayments.

Transformation of land cover and hydrologic function of small marine discharges via urbanization

At this point, urbanization only seems to be negatively affecting one pocket estuary in any significant way and that is Roche Harbor on San Juan Island. See Figure E-4.4 in Appendix E for a list of this sub-basin's pocket estuaries and stressors noted in our review of oblique aerial photos.

Transformation of habitat types and features via colonization by invasive plants

Spartina spp is not found here. Also, 44% of the shoreline (171 miles) contains *Sargassum muticum*, which may be patchy or continuous.

B. Evaluation

In this section we list goals and evaluate the level of realized function for natal and non-natal Chinook, summer chum, and bull trout. From this we then list each of the proposed protection and restoration actions for this sub-basin, and describe the benefits to natal Chinook, non-natal Chinook, and summer chum and bull trout (if any).

Goals for listed salmon and bull trout whose natal streams are outside this sub-basin

a) Provide support (migratory corridor and foraging functions) for all neighboring Puget Sound populations (sub-adult and adult), as well as support for adult salmon from Columbia and Snake River ESU's.
a) Provide for connectivity of habitats; also, adequate prey resources, marine foraging areas, and migratory corridors for sub-adult and adult Chinook.
b) Improve the knowledge of understanding of the diversity of life history type use in this sub-basin (i.e., it's not just juveniles, it's sub-adults and adults). Potential for large diversity (fish ranging in size from 60 to 150 mm (i.e., different age classes)).

Realized function for listed salmon and bull trout

Fry migrant Chinook – Only the easternmost shorelines of this sub-basin are within ten miles of natal deltas in the South Georgia Strait so few if any fry migrants are expected to use this sub-basin unless extreme flood events force small fish in that direction (Fig. E-3.2). In that event, low energy shorelines are available for rearing but few pocket estuaries are present.

Delta fry chinook – Delta fry are not expected to be present.

Parr migrant Chinook – Parr migrants from many populations could reach the San Juan Islands find support by the diversity of landscape classes found there. If exploited by parr migrants from neighboring populations, forage fish production becomes an important component of salmon survival. As in the South Georgia Straits sub-basin during even-numbered years, competition with pink salmon for prey resources may potentially impact Chinook salmon survival.

Yearling Chinook – Similar to parr migrants, the diversity of habitat types found within this sub-basin should support yearlings from other populations. Since this sub-basin lacks a natal delta, however, the importance of smaller salmon life history types as a food source for yearlings is likely much less than in other sub-basins. However, forage fish production and availability is very important to these larger-sized salmon emanating from neighboring populations. As in the South Georgia Strait sub-basin during even-numbered years, competition with pink salmon for prey resources may affect Chinook salmon survival.

Sub-adult and adult Chinook – We hypothesize that the survival of sub-adult and adult Chinook salmon is greatly dependent on the production and availability of forage fish species within nearshore regions of this sub-basin. In addition, marine vegetation such as eelgrass and kelp also play an important role in salmon survival. As in the South Georgia Strait sub-basin during even-numbered years, competition with pink salmon for prey resources may impact Chinook salmon survival.

Summer Chum – We hypothesize that Hood Canal/Eastern Strait of Juan de Fuca summer chum salmon do not use this sub-basin.

Bull Trout – We hypothesize that anadromous bull trout do not use this sub-basin

Table 6-8. Recommended protection actions for the San Juan Islands

Protection Action	**Benefit to Natal Chinook**	**Benefit to Other (non-natal) Chinook**	**Benefit to summer chum, bull trout, other fish**
Protect diversity of habitats (e.g., eelgrass, kelp) important for sustaining forage fish species throughout their life history, not just spawning habitat		Sustained feeding and growth of juveniles, sub-adults, and adults of all populations	Sustained feeding, growth, migration functions for all species

Protection Action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Aggressively protect the 16 pocket estuaries designated in this analysis as properly functioning		Sustained feeding, refuge, migration and growth of juveniles, sub-adults, and adults of all populations	Sustained feeding, growth, migration functions for all species
Protect against catastrophic events (many different populations use this sub-basin)		Sustained migration functions for all populations	Sustained migration functions for all species
Protect shoreline protection targets 1,2, 5, and 7-14		Sustained feeding function through forage fish production for all populations	Sustained feeding function through forage fish production for all species
Protect upland sediment sources within shoreline protection targets 3,4 and 6		Sustained feeding, refuge and migratory functions for all populations	Sustained feeding, refuge and migratory functions for all species

Table 6-9. Recommended improvement actions for the San Juan Islands

Improvement Action	Benefit to natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Protect juvenile salmon along shorelines by revisiting or revising the timing of in-water activities (e.g., construction, etc.) later in the calendar year (i.e., juvenile salmon are found to utilize nearshore regions later in the year than previously thought)		Improved growth, migration functions for all populations	Improved growth, migration for all species
Consider wastewater reclamation and reuse retrofits for Friday Harbor, Roche Harbor, Orcas and Rosario wastewater discharges		Improved feeding and refuge functions for all populations	Improved feeding and refuge for all species

6.5 Admiralty Inlet

A. Assessment

In this section we assess salmon and bull trout use, food web and ecological condition, landscape condition, and threats.

1. Salmon Use

Chinook

The TRT has identified no independent populations emanating from this sub-basin.

a) Juvenile
- All populations use this sub-basin, especially salmon populations from the main basin of Puget Sound (See Figure 3-1 for a list of all Chinook populations). This sub-basin provides direct support to meeting the Chinook ESU criteria by supporting rearing of juveniles of all populations from all five Geographic Regions of origin.
- Juvenile Chinook salmon from neighboring populations utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor.

b) Adult
- Sub-adult and adult salmon from Puget Sound populations utilize habitats within this sub-basin as a passage corridor and grazing area. Chinook are documented to use Gamble Creek and other regions in this sub-basin (See Fig. E-5.1). This sub-basin provides direct support to meeting the Chinook ESU criteria by supporting rearing of sub-adults and adults of all populations from all five Geographic Regions of origin.
- Adult salmon from far outside Puget Sound (e.g., Columbia River and Snake River ESU's) may utilize habitats within this sub-basin as a migratory corridor and foraging area.

Other Listed Species (not comprehensively reviewed or assessed for this sub-basin)
- Chum salmon: Populations of the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU do not emanate from this sub-basin. Non-natal use by populations from Hood Canal/Eastern Strait of Juan de Fuca may occur, but it is not known for certain. Historically, summer chum used Chimacum Creek.
- Bull trout (anadromous): Preliminary core populations (from core areas) within the Puget Sound Management Unit of bull trout do not exist in this sub-basin. It is not known if populations from northern Hood Canal use this sub-basin as forging, migration or overwintering habitat.

2. Ecological and Landscape Conditions

Food Web, Ecological Conditions

Admiralty Inlet is the conduit through which southern populations of Chinook must pass through to reach the Strait of Juan de Fuca. Populations from the Whidbey Basin may also use Admiralty Inlet to reach the Strait of Juan de Fuca, in addition to using Deception Pass to the north. Admiralty Inlet is mostly an open water region with relatively extreme weather and beach action. Deep, dense, saline waters from the ocean and Strait of Juan de Fuca enter Admiralty Inlet and flow south to the Main Basin and north toward Possession Sound and the Whidbey Basin (Ebbesmeyer et al, 2002). Surface currents mostly exit Puget Sound through Admiralty Inlet and then out to the Strait (Ebbesmeyer et al, 2002). This sub-basin is an important place in the Sound where mixing between oxygen rich waters and outflowing surface waters occurs. Primary and secondary production depends on the right mix of nutrients, light and oxygen. Van Voorhis et al. (2002) reported a pattern of nutrient limitation near the end of summer snow melt, as well as during winter months.

Forage fish are an important component of the diet of outmigrating juveniles and sub-adults in this sub-basin. Pacific herring are found in Kilisut Harbor and the Port Gamble area, and sand lance and surf smelt spawning beaches are found in the same regions, as well as scattered along both east and west shores.

Admiralty Inlet is the major corridor for commercial and recreational vessel traffic in Puget Sound. The potential for oil spills and other contamination would potentially be catastrophic to many salmon populations using this sub-basin as a foraging and migratory corridor to and from the Strait of Juan de Fuca.

Landscape Conditions

In addition to large open water fetches that generate strong wave action, tidal currents are important in shaping nearshore features within this sub-basin. Tall sandy bluffs dominate the shorelines of Admiralty Inlet providing an ample sediment source for beaches, spits and shallow subtidal shelves.

Further depiction of landscape conditions is presented in Appendix E, Figures E-5.1 through E-5.5.

Pocket Estuary Analysis

Our visual analysis of pocket estuaries in this sub-basin revealed 29 pocket estuaries Most are within the southern edge of Port Townsend and Oak Bay/ Kilisut Harbor and the Port Ludlow region (see Fig. E-5.4). Among the results were:

- Freshwater sources were observed in just over one-half the pocket estuaries,
- Based on the assumptions listed in Appendix B, all three of the Chinook functions (feeding, osmoregulation and refuge) were estimated to occur in 13 of the 29 pocket

Overall area

- Total area (deep-water plus nearshore) is 84,864 acres (132.6 square miles).
- Deep-water portion (marine waters landscape class) comprises 63,296 acres (98.9 square miles), or 75% of the total sub-basin area.

Nearshore area

- Nearshore portion comprises 21,568 acres (33.7 square miles), or 25% of the total sub-basin area. A natal estuary (landscape class) is not present in this sub-basin.
- Nearshore area within this sub-basin is 5% of the nearshore area of the entire Puget Sound basin.
- Contains 147 miles of shoreline (beaches landscape class).
- The "key" bays (landscape class) identified in this sub-basin are Port Gamble, Port Ludlow, Mats Mats Bay, Oak Bay, Kilisut Harbor, and Port Townsend.
- Twenty-five linear miles (17%) of the shoreline is designated as marine riparian (defined as the estimated area of length overhanging the intertidal zone).
- In this sub-basin, 67% of the shoreline (99 linear miles) has eelgrass (*Zostera marina* and *Z. japonica*); may be patchy or continuous.
- In this sub-basin, 11% of the shoreline (16 linear miles) has floating kelp; may be patchy or continuous. Also in this sub-basin, 29% of the shoreline (43 linear miles) has non-floating kelp; may be patchy or continuous.

estuaries. Most of the remaining pocket estuaries were estimated to have two of the three Chinook functions,

- Fifteen pocket estuaries were estimated to be *properly functioning*. Five pocket estuaries were estimated to be *not properly functioning*. The remaining pocket estuaries were recorded as *at risk*.

Drift Cell Analysis

There are a number of large, relatively unarmored drift cells within Admiralty Inlet sub-basin. These are regionally important protection targets because of the length of shoreline they occupy and their current condition and function. The drift cell characterization developed for this sub-basin is presented in Appendix E, Figure E-5.5 and subsequent text. Littoral drift, feeder sources, deltaic processes, deposition, and recommendations for protection and restoration are discussed in Appendix E and highlights of recommendations for protection and restoration included in Tables 6-10 and 6-11.

Threats/stressors

Loss and/or simplification of delta and delta wetlands

Natal estuaries for Chinook salmon do not occur in this sub-basin. No information is presented for smaller, non-natal deltas and delta wetlands.

Alteration of flows through major rivers

Larger-scale flow alterations are not present in this sub-basin. Smaller dams and diversions likely exist but are not identified here.

Modification of shorelines by armoring, overwater structures and loss of riparian vegetation/LWD

Shoreline armoring occurs along 17 miles (13%) of the shoreline. Over 11 miles of shoreline are classified as 100% armored. Ninety-nine miles are classified as 0% armored. The total number of overwater structures in this sub-basin is 1,379, consisting of ramps (56), piers and docks (273), small slips (1,032) and large slips (18). Railroads occur along 0.1 miles of shoreline in this sub-basin.

Contamination of nearshore and marine resources

See Figure E-5.3 for a depiction of water quality impairments in this sub-basin.

Alteration of biological populations and communities

There are two fish hatcheries adjacent to this sub-basin. Shellfish aquaculture is distributed mainly within protected embayments like Kilisut Harbor, Oak Bay and Port Gamble.

Transformation of land cover and hydrologic function of small marine discharges via urbanization

Seven pocket estuaries within the sub-basin are currently experiencing stress from urbanization to varying degrees including South Point, Port Ludlow and Chimacum Creek. See Figure E-5.4 for a list of pocket estuaries and noted stressors from visual observation via oblique aerial photos.

Transformation of habitat types and features via colonization by invasive plants

Spartina spp is not found in this sub-basin. Also, 10% of the shoreline (14 miles) contains *Sargassum muticum*, which may be patchy or continuous.

B. Evaluation

In this section we list goals and evaluate the level of realized function for natal and non-natal Chinook, summer chum, and bull trout. From this we then list each of the proposed protection and restoration actions for this sub-basin, and describe the benefits to natal Chinook, non-natal Chinook, and summer chum and bull trout (if any).

Goals for listed salmon and bull trout whose natal streams are in this sub-basin

a) The TRT identified no independent populations in the sub-basin, but that the sub-basin does provide early marine support for the Chinook documented to occur in Gamble Creek.

Goals for listed salmon and bull trout whos natal streams are outside this sub-basin

a) Provide support/use for all populations using this sub-basin, especially main basin Chinook populations. This area is a bottleneck, and for populations from the Stillaguamish, Snohomish and Skagit, this is the principle corridor to reach the Pacific Ocean via the Strait of Juan de Fuca. Fewer fish are thought to use Deception Pass as a corridor.
b) Chum salmon use of this area is not sufficiently known, although some historic use did occur in one stream approximately 20 years ago.
c) Fish in this sub-basin are not necessarily of small size; therefore the fish are not necessarily tied to shallow water habitats. Adequate water quality is critical to salmon in this sub-basin
d) Provide for connectivity of habitats; also, adequate prey resources, marine foraging areas, and migratory corridors for sub-adult and adult Chinook.

Realized function for listed salmon and bull trout

Fry migrant Chinook – More than 50% of the pocket estuaries support conditions favorable to this life history type, most of these situated on the western shores of Admiralty Inlet and along areas with protected shorelines (Figures E-5.1 and E-5.2), and many in areas near eelgrass (i.e., continuous bands). However, the pocket estuaries and nearshore habitats of this sub-basin are a great distance from any natal Chinook salmon estuary (much greater than 10 miles). The nearest natal estuary producing Chinook salmon fry migrants is the Dungeness delta and it is unlikely this or any other small-sized fry migrant from a non-natal Chinook salmon population would utilize the nearshore habitats (pocket estuaries, shorelines) of this sub-basin, simply as a matter of proximity. Rather, the juvenile salmon observed in this sub-basin are more often larger-sized, most likely the size of parr migrants or yearling life history types.

The Hood Canal sub-basin produces fry migrants from the Hood Canal/Eastern Strait of Juan de Fuca Summer chum composite populations, and the degree to which, and if, small-sized chum salmon utilized nearshore habitats is not well understood. Therefore, it is unlikely the small-sized fish utilize this sub-basin, still a great distance from any of the central or northern Hood Canal Rivers (e.g., Duckabush, Dosewallips, Hamma Hamma) containing composite Hood Canal/Eastern Strait of Juan de Fuca Summer chum populations.

Delta fry Chinook - Natal estuaries that would account for independent populations of Chinook salmon do not exist, therefore this particular Chinook salmon life history type is not produced within Admiralty Inlet. That is not to say that smaller-sized juvenile salmon in the 50-60 mm size range do not occur along the shallow water, low-velocity regions of shoreline. Rather, as stated above, the juvenile salmon observed in this sub-basin are more often larger-sized, most likely the size of parr migrants or yearling life history types.

The west side of Admiralty inlet (North Kitsap Peninsula) is more likely to support early migrant Hood Canal/Eastern Strait of Juan de Fuca Summer chum from Northern Hood Canal rivers and which may ultimately extend significantly south into the Central Puget Sound Sub-basin toward Kingston. The east side of Admiralty Inlet (West Whidbey Island) is more likely to support larger life history types of all populations of both Chinook and Hood Canal/Eastern Strait of Juan de Fuca Summer chum.

Parr migrant Chinook – Many of the Puget Sound Chinook salmon migrate to the ocean as sub-yearlings (Myers et. al., 1998), and on average this life history type is the most abundant in Puget Sound. By the time Chinook and Hood Canal/Eastern Strait of Juan de Fuca Summer chum salmon are the size of parr migrants (approximately >70 mm), the Admiralty Inlet sub-basin is realized as a critical nexus in Puget Sound. Most of the 22 independent populations of Chinook salmon, and all the Hood Canal/Eastern Strait of Juan de Fuca Summer chum salmon must pass through Admiralty Inlet to reach the Strait of Juan de Fuca en route to the Pacific Ocean for maturation. Any type of catastrophic event (e.g., oil spill) would significantly affect most if not all ESA-listed salmon populations within Puget Sound. Guarding against such an event is a critical step to safeguarding populations as they emigrate to the Pacific Ocean.

In addition to being the main conduit for salmon populations, salmon the size of a parr migrant derives functions (e.g., rearing, foraging, refuge) from habitats within the nearshore. The west and south side of Admiralty Inlet contains most of the sub-basin's pocket estuaries (functioning, at risk and some not functioning), protected shorelines and eelgrass bands. Along the western shore, parr migrants coming from Hood Canal, Whidbey Basin and central and south sound must also contend with two sewage outfalls and a region of low dissolved oxygen near the Hood Canal Bridge and also in Port Gamble.

Yearling Chinook – Any reduction in capacity as a result of non-support of the other life history types (i.e., primarily parr migrant and possibly delta fry) within this sub-basin will negatively affect yearling migrants. As with the parr migrants, yearlings must also pass through Admiralty Inlet to the Strait of Juan de Fuca en route to the Pacific Ocean and any catastrophic event would be disastrous to salmon populations. Yearlings emigrating from Hood Canal, central and south sound, and the Whidbey Basin can derive function (e.g., foraging, refuge, migratory pathway) from the relatively unarmored shorelines with sparse overwater structure, as well as accessing the functioning (and at risk) pocket estuaries and protected shoreline regions.

Sub-adult and adult Chinook – We hypothesize that the survival of sub-adult and adult Chinook salmon is likely dependent on the production and availability of forage fish species within nearshore regions of this sub-basin. In addition, marine vegetation such as eelgrass and kelp play an important role in salmon survival. An uncontaminated migratory corridor is critical to survival of the majority of Chinook populations in Puget Sound that must pass through this region.

Summer Chum – Hood Canal/Eastern Strait of Juan de Fuca summer chum salmon use the western shore of this sub-basin as outmigrant fry (Simenstad 2000a).

Bull Trout – We hypothesize that anadromous bull trout do not use this sub-basin

Table 6-10. Recommended protection actions for Admiralty Inlet

Protection Action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Aggressively protect all drift cell function that supports eelgrass bands and depositional features throughout the sub-basin. Consider designating these shorelines for the highest level of protection within county shoreline master programs and critical areas ordinances and pass strong policies limiting increased armoring of these shorelines. (Shoreline protection targets 1-6, 8,9,11,13 on Fig. E-5.5, Appendix E)		Sustained feeding function through forage fish production for all populations	Sustained feeding function through forage fish production for all species
Protect against catastrophic events		Sustained migration functions for all populations	Sustained migration functions for all species

Table 6-11. Recommended improvement actions for Admiralty Inlet

Improvement Action	Benefit to natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Restore drift cell functions in shoreline restoration targets 7,10,12 and 14 in Fig. E-5.5		Improved feeding function through forage fish production for all populations	Improved feeding function through forage fish production for all species

6.6 Whidbey Basin

1. Salmon Use

Chinook

10 of 22 independent populations emanate from this sub-basin:

- Lower Skagit
- Upper Skagit
- Cascade
- North Fork Stillaguamish
- South Fork/Mainstem Stillaguamish
- Suiattle
- Lower Sauk
- Upper Sauk
- Skykomish

- Snoqualimie

a) Juvenile

- Juvenile Chinook salmon of all four life history types for all 10 natal populations utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor (juvenile salmon functions).
- Juvenile Chinook salmon from neighboring populations utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor.

b) Adult

- Sub-adult and adult salmon from Puget Sound populations utilize habitats within this sub-basin as a migratory corridor and grazing area.

Other Listed Species (not comprehensively reviewed or assessed for this sub-basin)

- Chum salmon: Natal populations of the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU do not exist in this sub-basin. Non-natal use may occur, but it is not known for certain.
- Bull trout (anadromous): The Puget Sound Management Unit contains four core areas in this sub-basin (Snohomish/Skykomish, Stillaguamish, Upper Skagit, Lower Skagit). With the exception of the Upper Skagit core area, each core area is critical for sustaining the distribution of the anadromous bull trout life history trait within Puget Sound. In particular, the Lower Skagit core area is absolutely essential for this management unit. Bull trout from other basins are confirmed to use the Snohomish River estuary (USFWS 2004). Finally, the four core areas contain an estimated 33 local populations, greater than 3500 adult fish (estimated) and population trends varying from unknown to stable to increasing (USFWS 2004).

2. Ecological and Landscape Conditions

Food Web, Ecological Conditions

Whidbey basin and its nearshore environment is a unique region of Puget Sound. The Skagit, Snohomish and Stillaguamish are the three largest rivers in Puget Sound and all empty in the Whidbey Basin (Figure E-5.1), generating a strong surface outflow from Possession Sound (Ebbesmeyer et al, 2002). Of these rivers, the Skagit River is the largest source of freshwater flowing into Puget Sound. The depth of the density gradient in Possession Sound is close to the surface and well stratified (Van Voorhis et al, 2002), indicative of the large volume of freshwater flow into Whidbey Basin. A reduction of freshwater flow can affect the stratification. Portions of Whidbey basin are susceptible to low levels of D.O. (due in part to slower circulation and nutrient input) and poor water quality (e.g., lower Stillaguamish – West Pass). During low freshwater flows the water can heat up and the D.O. can decrease. Nutrient limitation can be pronounced in Possession Sound, and Van Voorhis et al, (2002) reported a pattern of nutrient limitation near the end of summer snowmelt.

Landscape Conditions

Because of the extreme influence of freshwater, the entire Whidbey Basin behaves like a giant estuary with all shorelines being affected by river discharge and sedimentation. Because the Snohomish and Stillaguamish are much older river deltas than the Skagit, the extent of tidal influence can be measured far upstream from the delta face and many important estuarine habitats are within distributary sloughs of the river channel, not in a deltaic fan offshore in the bay. The effect of strong southerly winds from the central basin and restricted tidal connection through Deception Pass coupled with the potentially high nutrient loads from the rivers, the waters of Whidbey Basin can become eutrophic.

See Figures E-5.1 through 5.3, E-6.4 and 6.5 in Appendix E for additional information about landscape conditions.

Overall area

- Total area (deep-water plus nearshore) is 157,631 acres (246.3 square miles).
- Deep-water portion (marine waters landscape class) comprises 80,128 acres (125.2 square miles), or 51% of the total sub-basin area.

Nearshore area

- Nearshore portion comprises 77,440 acres (121.0 square miles), or 49% of the total sub-basin area. As part of the nearshore, the Skagit, Stillaguamish and Snohomish estuaries are natal estuaries (landscape class) for the independent Chinook populations listed above, comprising 74.25 square miles (61%) of the total nearshore area within this sub-basin.
- Nearshore area within this sub-basin is 19% of the nearshore area of the entire Puget Sound basin.
- Contains 352 miles of shoreline (beaches landscape class).
- The "key" bays (landscape class) identified in this sub-basin are Similk Bay, Dugula Bay, Crescent Harbor, Oak Harbor, Penn Cove, Holmes Harbor, Livingston Bay, Triangle Cove, and Tulalip Bay.
- Fifty-six linear miles (16%) of the shoreline is designated as marine riparian (defined as the estimated area of length overhanging the intertidal zone).
- In this sub-basin, 46% of the shoreline (162 linear miles) has eelgrass (*Zostera marina* and *Z. japonica*); may be patchy or continuous.
- In this sub-basin, 2% of the shoreline (6 linear miles) has floating kelp; may be patchy or continuous. Also in this sub-basin, 7% of the shoreline (24 linear miles) has non-floating kelp; may be patchy or continuous.

Pocket Estuary Analysis

We identified 17 pocket estuaries in this sub-basin: two in Skagit Bay, several scattered throughout Saratoga Passage, and several in Port Susan and Possession Sound.

- Freshwater sources were observed in nine of 17 pocket estuaries,
- Based on the assumptions listed in Appendix B, all three of the Chinook functions (feeding, osmoregulation and refuge) were estimated to occur in six of the 17 pocket estuaries,
- Two pocket estuaries were estimated to be *properly functioning*. Six pocket estuaries were estimated to be *not properly functioning*. The remaining pocket estuaries were recorded as *at risk*.

Drift Cell Analysis

The complexity of Whidbey Basin shoreforms is as a result of a complex interplay between river sediments and longshore drift processes that affect steep sandy bluffs. The stability of these bluffs compared to Admiralty Inlet means that landslides or other mass wasting effects may be more important to add sediment to beaches than wave generated bluff erosion. The drift cell characterization for this sub-basin and is presented in Figure E-5.5 and subsequent text in Appendix E. Littoral drift, feeder sources, deltaic processes, deposition, and recommendations for protection and restoration are discussed in Appendix E and highlights of recommendations for protection and restoration are included in Tables 6-10 and 6-11.

Threats/stressors

Loss and/or simplification of delta and delta wetlands

Comparison of historical wetland area and wetland area reported in Bortleson et al. (1980) revealed that for the Skagit delta, the estimate area of subaerial wetlands decreased from historical to date of survey in 1980 from 6.18 to 4.63 square miles (decreased by 1.55 square miles). The estimated area of intertidal wetlands could not be calculated because historical estimates were not provided. In 1980, 21.24 square miles of intertidal wetlands were reported.

Comparison of historical wetland area and wetland area reported in Bortleson et al. (1980) revealed that for the Stillaguamish delta, the estimate area of subaerial wetlands increased from historical to date of survey in 1980 from 1.15 to 1.39 square miles (increased by 0.24 square miles). The estimated area of intertidal wetlands could not be calculated because historical estimates were not provided. In 1980, 7.72 square miles of intertidal wetlands were reported.

Comparison of historical wetland area and wetland area reported in Bortleson et al. (1980) revealed that for the Snohomish delta, the estimate area of subaerial wetlands decreased from historical to date of survey in 1980 from 15.06 to 3.86 square miles (decreased by 11.2 square miles). The estimated area of intertidal wetlands decreased from historical to date of survey in 1980 from 5.01 to 3.40 square miles (decreased by 1.61 square miles). The change in wetland habitat area between historical and current (1970's) condition in the Snohomish estuary is substantial. However, many of the agricultural lands made possible by historical diking are no longer actively worked. Thus, the Snohomish estuary offers significant opportunity for restoration.

Delta building (progradation) has occurred in the Stillaguamish River due to its quiet receiving waters, whereas in the Skagit and Snohomish delta, delta building has been less so because of the marine water's ability to move sediment from the delta front (Bortleson et al, 1980).

Historically, estuarine wetlands were extensive in the Skagit-Samish delta, consuming an area more than twice that of the Nooksack, Stillaguamish and Snohomish deltas, combined (Collins et al, 2003). Diking and draining of wetlands has reduced the area. The most extensive changes have occurred in the valley wetlands and loss of valley floor forests where most of the dense river bottom forests in Puget Sound have been eradicated (Collins et al, 2003). In a reconstruction analysis, Collins et al, (2003) showed the Stillaguamish River system was once similar to the Nisqually River (anastomosing pattern). Prior to extensive modification of the landscape by settlers, large floodplain wetlands and extensive estuarine marshes "accounted for nearly two-thirds (62%) of the valley bottom" of the Snohomish River (Collins et al, 2003). The removal of instream LWD has also impacted the Skagit, Snohomish and Stillaguamish river systems (Collins et al, 2003). The lower Snohomish and Stillaguamish River systems have been dramatically altered. In the Skagit River alone, between 1898 and 1908, 30,000 snags were removed (Collins et al, 2003).

Alteration of flows through major rivers

Three dams are located on the upper Skagit River, and are believed to be located in an area of a historical migration barrier (USFWS 2004). The flow regime downstream of Skagit River must adhere to Skagit Hydroelectric Project Fisheries Settlement Agreement (USFWS 2004). The three dams in the upper Skagit system have altered the transport of LWD to the lower river and Skagit estuary, resulting in reduced habitat complexity as compared to historical conditions (USFWS 2004).

Modification of shorelines by armoring, overwater structures and loss of riparian vegetation/LWD

The projected population growth in Skagit and Snohomish counties between 2000-2025 is 60% (61, 818 people) and 53% (323,290 people), respectively (PSAT 2004). In this sub-basin, shoreline armoring occurs along nearly 152 miles (44%) of the shoreline. One hundred forty four miles of shoreline are classified as 100% armored. Over 190 miles are classified as 0% armored. The total number of overwater structures is 5,046, consisting of ramps (169), piers and docks (369), small slips (4,390) and large slips (118). Overwater structure are observed intermittently throughout the sub-basin, and are concentrated in the Snohomish estuary (Everett region), and the LaConnor region. Within 300 feet of shore railroad grades occur along 3.8 miles, following the eastern shoreline from Mukilteo north to Everett. See the loss and/or simplification of deltas and delta wetlands piece (above) for a discussion on the loss of LWD.

Contamination of nearshore and marine resources

Regions with 15% or greater impervious surface area are concentrated in the Marysville and Everett area, as well as Oak Harbor (PSAT 2004). In this sub-basin, Everett Harbor is one point source for contaminants such as from sewage and toxic contaminants (Washington Sea Grant, 2000). Potential non-point sources of contamination include stormwater runoff and failing septic systems (Washington Sea Grant, 2000). Surveys in 1996-1997 show depressed dissolved oxygen concentrations in Penn Cove (Washington Sea Grant, 2000), a region especially susceptible and sensitive to eutrophication (PSWQAT 2002a). The Skagit and Snohomish Rivers, comprising 47% of the Puget Sound Basin, contribute 50% of the nutrient loads (Embrey and Inkpen 1998). See the discussion in Ecological Conditions for more on water quality and dissolved oxygen.

Whidbey Basin is second only to central Sound in the degree of degraded sediments (PSAT 2002a). Chemical concentrations in Puget Sound sediments are typically greater in urban/industrialized regions, such as in Everett Harbor (PSAT 2002a). Nine percent of the area of this sub-basin exceeds the state's sediment quality standards and the cleanup screening levels.

Figure E-5.3 presents the distribution of water quality impairments across the sub-basin.

Alteration of biological populations and communities

The number of hatcheries operating in this sub-basin is 10. Specific hatchery reform recommendations for this region have been formulated by the Hatchery Scientific Review Group available at the following websites.
http://www.lltk.org/pdf/HSRG_Recommendations_February_2002.pdf
http://www.lltk.org/pdf/HSRG_Recommendations_March_2003.pdf

Shellfish aquaculture is not practiced in this sub-basin to any significant degree because of proximity to urban centers and potential bacterial contamination. A small shellfish aquaculture operation occurs within Triangle Cove.

Transformation of land cover and hydrologic function of small marine discharges via urbanization

Warm Beach and Tulalip Bay are considered at risk for salmon functions largely due to impacts of urbanization. See Figure E-6.4 for a list of pocket estuaries and stressors noted in a review of oblique aerial photos.

Transformation of habitat types and features via colonization by invasive plants

Nine percent of the shoreline (33 miles) in this basin contains patchy or continuous *Spartina spp.*. Also, 4% of the shoreline (13 miles) contains *Sargassum muticum*, which may be patchy or continuous.

B. Evaluation

In this section we list goals and evaluate the level of realized function for natal and non-natal Chinook, summer chum, and bull trout. From this we then list each of the proposed protection and restoration actions for this sub-basin, and describe the benefits to natal Chinook, non-natal Chinook, and summer chum and bull trout (if any).

Goals for listed salmon and bull trout whose natal streams are in this sub-basin

a) Provide early marine support for all four life history types (fry migrants, delta fry, parr migrants, yearlings) for the 10 independent populations of Chinook salmon emanating from this sub-basin,
b) Provide support for sub-adult and adult Chinook salmon populations who utilize habitats within this sub-basin as a migratory corridor and grazing area.
c) Provide marine support for sub-adult and adult anadromous bull trout populations (approximately 33) within the four core areas in this sub-basin (Snohomish/Skykomish, Stillaguamish, Upper Skagit, Lower Skagit). The Lower Skagit core area is absolutely essential to sustaining the distribution of the anadromous bull trout life history trait within Puget Sound.
d) Provide for connectivity of habitats; also, adequate prey resources, marine foraging areas, and migratory corridors for juvenile, sub-adult and adult Chinook, and bull trout.

Goals for listed salmon and bull trout whose natal streams are outside this sub-basin

a) Provide support for all neighboring Puget Sound populations (juveniles, sub-adults, and adults) that utilize nearshore and marine regions of this sub-basin as a migratory corridor.

Realized function for listed salmon and bull trout

Fry migrant Chinook – Fry migrants from each of the major rivers will be well supported by the abundance of low wave energy shorelines in this sub-basin, however, few pocket estuaries are currently available and most are in poor condition for supporting fry migrants (Figure E-5.2). This is more likely to affect this life history type during storm events. The frequent seasonal flooding of these systems is likely to disburse fry migrants widely throughout the sub-basin so it is expected that even pocket estuaries at some distance from the delta may serve natal functions during these events. Small streams embedded in shorelines may function as pocket estuaries. Any increase in armoring of residential shorelines is of concern for support of fry migrants. See Figure E-6.4 for a list of pocket estuaries and observed stressors. In addition, fry migrants may be impacted by the concentration of overwater structures in the Snohomish estuary and the LaConnor region.

Delta fry Chinook – The three large natal deltas within this sub-basin have the potential to produce large numbers of delta fry. The Snohomish delta has large amounts of potential habitat to support this life history type upstream of Everett because the tidal influence continues several miles inland. However, much of that potential habitat is locked up behind older industrial and agricultural infrastructure as well as ongoing uses. Considerable ongoing restoration within this delta is expected to greatly improve the support for delta fry. Delta fry in the Snohomish estuary, however, will be more exposed to poor water quality conditions in Everett Harbor due to contaminant loadings from toxics and sewage discharges (Figure E-5.3) than delta fry from the other two estuaries. Contaminated sediments and impaired invertebrate communities in Everett Harbor will likely impact this life history type. The Stillaguamish and Skagit deltas are greatly reduced in size compared to their historic condition, largely from agricultural diking. Delta fry support is likely to be a mere fraction of the historic condition. Only limited tidal restoration has occurred in these deltas and much more will be needed to significantly boost this important life history type.

Parr migrant Chinook – Parr migrants will be well supported by the large numbers of smaller life history types and forage fish within the sub-basin as a food source. Parr migrants from main basin populations also use the protected shorelines of this sub-basin for support. The density of fish in this sub-basin from these three deltas and neighboring sub-basins may suggest that competition is a factor in supporting this life history type.

In addition, poor water quality and contamination will likely impact this life history type. Low dissolved oxygen in the lower Stillaguamish, Penn Cove, and Possession Sound may pose a problem for this life history type as the fish are migrating throughout the sub-basin searching for forage. Contaminated sediments and impaired invertebrate communities in Everett Harbor may also impact this life history type.

Yearling Chinook – An abundance of forage fish and smaller life history types are available as a food source within this sub-basin so yearlings should be well supported. However, poor water quality and contamination may impact this life history type. Low dissolved oxygen in the lower Stillaguamish, Penn Cove, and Possession Sound may pose a problem for this life history type as the fish are migrating throughout the sub-basin searching for forage. Contaminated sediments and impaired invertebrate communities in Everett Harbor may impact this life history type.

Sub-adult and adult Chinook – We hypothesize the survival of sub-adult and adult Chinook salmon is likely dependent on several factors: the production and availability of forage fish species within nearshore regions, adequate water quality, low contamination levels and a healthy food chain, and the presence of marine vegetation, among others. Low dissolved oxygen levels and a reduction in prey, as well as contaminated food sources in the regions mentioned above have the potential to impact outmigrating sub-adults and returning adults.

Listed summer chum – We hypothesize that Hood Canal/Eastern Strait of Juan de Fuca summer chum salmon do not use this sub-basin.

Anadromous bull trout – The Snohomish/Skykomish, Stillaguamish, and Lower Skagit core areas are critical for sustaining the distribution of the anadromous bull trout life history trait within Puget Sound (USFWS 2004). The Whidbey Basin's estuaries and nearshore waters provides critical foraging, migration, and overwintering habitats for sub-adult and adult anadromous bull trout. As in other sub-basins containing populations of anadromous bull trout, fish in this sub-basin feed on many prey items in productive shallow waters (USFWS 2004). As with yearling Chinook, and sub-adult and adult Chinook, bull trout may be impacted by poor water quality in estuarine and nearshore regions (e.g., Snohomish River, Penn Cove, Possession Sound), as well as contamination of sediments and prey items. Also, the loss of LWD in lower reaches of large rivers (e.g., Skagit), and estuaries, has reduced habitat complexity and can potentially impact bull trout.

All life history types in this sub-basin may be at risk from low dissolved oxygen from sewage discharges and poor oceanographic flushing.

This sub-basin is key to the viability of Chinook salmon and anadromous life forms of bull trout.

Table 6-12. Recommended protection actions for Whidbey Basin

Protection Action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Protect all deltas, shorelines and pocket estuaries within the entire basin from further degradation, particularly all three natal deltas, Similik and Tosi Point pocket estuaries and shoreline protection targets 3,5,6, 9-12 and 16 in Fig. E-6.5)	Sustained early marine support of all 4 life history types of Skagit, Stillaguamish and Snohomish populations (feeding and growth, refuge, osmoregulatory, migration functions). Addresses all four VSP parameters	Sustained support for neighboring Puget Sound populations (e.g., Lake Washington and Duwamish Chinook, larger juveniles from other populations). Functions addressed: feeding and growth, refuge, osmoregulatory, migration	Sustained support for anadromous bull trout and other species. Functions addressed: feeding and growth, refuge, osmoregulatory, migration
Protect water quality within the sub-basin. There is the potential for dissolved oxygen problems/eutrophication due to excessive nutrient input (sewage outfalls, spills, agricultural). Prevent further degradation of D.O. and other water quality factors including avoidance of further stormwater loadings and NPDES discharge loadings	Sustained growth of all 4 life history types of Skagit, Stillaguamish and Snohomish populations.	Sustained migration functions for Lake Washington and Duwamish and other populations	Sustained growth of anadromous bull trout and other species.
Protect against catastrophic events	Sustained feeding, growth, osmoregulation, refuge and migration functions for all 3 natal populations	Sustained migration functions for all populations	Sustained migration functions for other species; feeding, growth, osmoregulation and refuge for anadromous bull trout
Ensure the amount of fresh water flowing into this sub-basin remains constant and does not drop to lower levels through added diversions, withdrawals, etc. A loss of freshwater may precipitate eutrophication and low DO in Possession Sound	Sustained growth of all 4 life history types of Skagit, Stillaguamish and Snohomish populations.	Sustained migration functions for Lake Washington and Duwamish and other populations	Sustained growth of anadromous bull trout and other species.

Table 6-13. Recommended improvement actions for Whidbey Basin

Improvement Action	Benefit to natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Consider wastewater reclamation and reuse retrofits for all sewage discharge facilities within the sub-basin. Redirection of sewage treatment discharges to upland treatment and reuse/recharge systems will help to reduce summer time loadings that are degrading D.O. levels and shifting nearshore community structure.	Improved feeding, growth, and migration functions for all three natal populations	Improved feeding and migration functions for other populations	Improved feeding, growth and migration functions for anadromous bull trout and other fish species
Restore all three major deltas by removing agricultural levees and navigational structures that impede natural sediment and tidal processes in shoreline target areas 1,2,4 and 15 in Fig. E-6.5	Improved feeding, growth, refuge, osmoregulation and migration of all 4 life history types of all three natal populations	Improved feeding, growth, refuge and migration of other populations, especially Lake Washington and Duwamish	Improved feeding, growth, refuge, osmoregulation and migration of anadromous bull trout and other fish species
Restore all at risk pocket estuaries within the sub-basin, which includes Elger Bay, Triangle Cove, Livingston, Warm Beach, Tulalip Bay, Honeymoon Bay, Race Lagoon and Penn Cove	Improved feeding, growth, refuge, osmoregulation and migration of all 4 life history types of all three natal populations	Improved feeding, growth, refuge and migration of other populations, especially Lake Washington and Duwamish	Improved feeding, growth, refuge, osmoregulation and migration of anadromous bull trout and other fish species
Restore all shoreline restoration targets within the sub-basin (areas 7,8,13 and 14 in Fig. E-6.5)	Improved feeding and migration functions for all 3 natal populations	Improved feeding and migration for other populations	Improved feeding and migration for anadromous bull trout and other fish species
Re-create hydrologic connections of Skagit Bay to both Padilla Bay and Stillaguamish delta to restore access to South Georgia Straits/Padilla Bay/Whidbey sub-basins corridor for Chinook migrants from all populations originating in the Whidbey Basin and South Georgia Straits sub-basins	Improved migration functions for Snohomish, Stillaguamish and Skagit populations (addresses spatial structure and diversity VSP)	Improved migration for Duwamish, Lake Washington and Nooksack populations. (addresses spatial structure and diversity VSP)	Improved migration functions for anadromous bull trout and other fish species (addresses spatial structure and diversity VSP)
Conduct a prioritized cleanup of contaminated sediment hot spots and ongoing toxic discharges in the Everett Harbor area	Improve connectivity between the Snohomish delta and other landscape classes for sensitive life history types such as fry migrants		Improve connectivity between the Snohomish delta and other landscape classes for anadromous bull trout and other fish species

6.7 Hood Canal

1. Salmon Use

Chinook

The TRT has identified two independent populations emanating from this sub-basin:
- Skokomish
- Mid-Hood Canal

a) Juvenile
- Juvenile Chinook salmon of all four life history types from the Skokomish and mid-Hood Canal populations utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor (juvenile salmon functions).
- Juvenile Chinook salmon from non-natal populations (e.g., Elwha and Dungeness) utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor.
- Chinook are documented in, and may spawn in, numerous other Hood Canal streams including Dewatto River, Big Beef Creek, and Lilliwaup Creek.

b) Adult
- Sub-adult and adult salmon from Puget Sound populations utilize habitats within this sub-basin as a migratory corridor and grazing area.
- Adult Chinook salmon from non-natal populations (specifically, Elwha and Dungeness populations) also utilize this sub-basin

Other Listed Species (not comprehensively reviewed or assessed for this sub-basin)
- Chum salmon: Six natal populations (Big and Little Quilcene, Dosewallips, Duckabush, Hamma Hamma, Lilliwaup and Union) of the Hood Canal/Eastern Strait of Juan de Fuca Summer chum ESU emanate from this sub-basin.
- Bull trout (anadromous): The Olympic Peninsula Management Unit contains one core area in this sub-basin (Skokomish), comprised of two populations. It is believed that anadromous bull trout may inhabit this core area. A larger region adjacent to the Skokomish drainage provides important foraging, migration, and overwintering habitat for sub adult and adult anadromous bull trout (USFWS 2004). Currently, the extent of the Skokomish population's use of this sub-basin is not known, but bull trout have been observed, historically, in several Hood Canal tributaries (e.g., Quilcene, Dosewallips, Duckabush, and Hamma Hamma River) (USFWS 2004).

2. Ecological and Landscape Conditions

Food Web, Ecological Conditions

Hood Canal is a long fjord with five major rivers contributing freshwater input, and contains a shallow east-west sill south of the Hood Canal Bridge, considerably more shallow than the areas immediately north or south of the sill (Fagergren et al, 2004). The natural geography of the region lends itself to an elevated natural sensitivity to nutrient input, due in part to slow flushing rates and the degree of stratification. As early as the 1950s, portions of Hood Canal experienced low dissolved oxygen levels, but since that time conditions have worsened (Fagergren et al, 2004). Persistent and worsening water quality problems, specifically low dissolved oxygen in the southern portion of Hood Canal continues to plague the ecosystem. Data from the 1990s revealed longer periods of time with biologically critical D.O. levels, hypoxic conditions, with low D.O. conditions possibly spreading to north Hood Canal (Fagergren et al, 2004). A pronounced and lengthy period of hypoxia in 2002 preceded a spring fish kill in 2003, followed by a widespread kill in the fall of 2003 (Fagergren et al, 2004). Dissolved oxygen levels during the winter of 2004 in south Hood Canal were the lowest on record (Fagergren et al, 2004).

The low D.O. conditions in Hood Canal may be a larger issue or problem for incoming adult salmon in the late summer or fall, rather than juvenile outmigrants because of the timing of hypoxic conditions. Forage fish, invertebrates like shrimp and octopus, rockfish and many other species are susceptible to mortality from hypoxia.

Harbor seal predation on returning adult salmon off the mouths of the Quilcene, Dosewallips, Duckabush, and Hamma Hamma river systems has been observed in 1998-2001. Seals were observed consuming summer chum, coho, and fall chum in all four years of observation. (VanBlaricom, et al, 2004) Additional surface observations were conducted in the fall of 2003 in order to assess the impact of an apparently large removal of seals by transient killer whales in Hood Canal during the winter of 2003. Although observations initially suggested major reductions in seal numbers, a more thorough evaluation of seal survey data suggests that the population-scale effect of the whale foraging event on harbor seals was small, and possibly even insignificant. This surprising result has led to reevaluation of broadly accepted assumptions about the metabolism and foraging ecology of transient killer whales, and suggests resilience of harbor seal populations to episodic attacks by predators. (VanBlaricom, et al, 2004)

Landscape Conditions

The shorelines of Hood Canal are a combination of low banks, sandy bluffs and rocky shorelines reflecting the complex geology of this fjord. The shorelines are punctuated by many stream and river mouths with broad deltaic fans, the largest of which is the Skokomish natal delta. The influence between these deltaic sediment sources and longshore sediment drift processes creates a shallow subtidal shelf in many areas that support extensive eelgrass patches. Between the patches is an almost continuous band of eelgrass along the steeper shorelines. A long history of Japanese oyster culture in Hood Canal resulted in the upper intertidal zone being almost completely colonized by living oysters or covered in empty oyster shells. The effect this cover has on the distribution of native plant and animal communities on beaches within Hood Canal is unknown.

The linkages between watersheds and natal and other estuaries are important to salmon as they move from freshwater to open marine waters (Simenstad 2000a). The estuaries, whether natal Chinook or summer chum estuaries, other estuaries with documented use by Chinook, summer chum, or bull trout, or pocket estuaries, are what Simenstad (2000a) refers to as “patches,” dispersed along the shorelines of Hood Canal. The connection between all estuaries is important to summer chum and Chinook salmon. Summer chum salmon in this sub-basin are especially dependent on eelgrass beds (Simenstad 2000a).

See Figures E-7.1 through E-7.5 in Appendix E for additional information about landscape conditions in Hood Canal.

Overall area

- Total area (deep-water plus nearshore) is 85,888 acres (134.2 square miles).
- Deep-water portion (marine waters landscape class) comprises 62,784 acres (98.1 square miles), or 73% of the total sub-basin area.

Nearshore area

- Nearshore portion comprises 23,104 acres (36.1 square miles), or 27% of the total sub-basin area. As part of the nearshore, the Skokomish estuary is a natal estuary (landscape class) for the independent Chinook populations listed above, comprising 2.96 square miles (8%) of the total nearshore area within this sub-basin.
- Nearshore area within this sub-basin is 5% of the nearshore area of the entire Puget Sound basin.
- Contains 203 miles of shoreline (beaches landscape class).
- The "key" bays (landscape class) identified in this sub-basin are Seabeck Bay, Stavis Bay, Dewatto Bay, Tahuya, Annas Bay, Lilliwaup Bay, Pleasant Harbor, Jackson Cove, Dabob Bay, Fishermans Harbor, Thorndike Bay, and Squamish Harbor.
- Fifty-eight linear miles (29%) of the shoreline is designated as marine riparian (defined as the estimated area of length overhanging the intertidal zone).
- In this sub-basin, 77% of the shoreline (156 linear miles) has eelgrass (*Zostera marina* and *Z. japonica*); may be patchy or continuous.
- In this sub-basin, floating kelp does not occur. In this sub-basin, 10% of the shoreline (21 linear miles) has non-floating kelp; may be patchy or continuous.

Pocket Estuary Analysis

We identified 39 pocket estuaries in this sub-basin. We analyzed these estuaries with Chinook salmon in mind: Using the Duckabush River as an approximate mid-point of this sub-basin, 15 pocket estuaries are located south of this point (most south of Hoodsport), and 24 are located north of the Duckabush River and relatively evenly distributed along both shorelines.

- Freshwater sources were observed in nearly three-quarters of the pocket estuaries,
- Based on the assumptions listed in Appendix B, all three of the Chinook functions (feeding, osmoregulation and refuge) were estimated to occur in 21 of the 39 pocket estuaries. Most of the remaining pocket estuaries were estimated to have two of the three Chinook functions,
- Eighteen pocket estuaries were estimated to be *properly functioning*. Seven pocket estuaries were estimated to be *not properly functioning*. The remaining pocket estuaries were recorded as *at risk*.

Drift Cell Analysis

Several long stretches of shoreline in northern and eastern Hood Canal remain unarmored and are expected to have high natural function of drift cell processes. The southern and western shorelines are almost completely armored by single family residential and commercial property bulkheads. A drift cell characterization for this sub-basin is presented in Appendix E, Figure E-7.5 and subsequent text. Littoral drift, feeder sources, deltaic processes, deposition, and recommendations for protection and restoration are discussed in Appendix E and highlights of recommendations for protection and restoration are included in Tables 6-14 and 6-15.

Threats/stressors

Loss and/or simplification of delta and delta wetlands

Comparison of historical wetland area and wetland area reported in Bortleson et al. (1980) revealed that for the Skokomish delta, the estimated area of subaerial wetlands decreased from historical to date of survey in 1980 from 0.81 to 0.54 square miles (decreased by 0.27 square miles). The estimated area of intertidal wetlands decreased from historical to date of survey in 1980 from 1.93 to 1.73 square miles (decreased by 0.20 square miles).

Jay and Simenstad (1996) compared pre- and post-diversion surveys and suggested deposition has occurred on much of the inner delta and erosion on much of the outer delta. Many of the historical bathymetric change cross-sections revealed a steepening of the delta surface, apparently "caused by a loss of sediment transport capacity in the lower river and estuary combined with steady or increased (due to logging) sediment supply." In addition, a 15-19% loss of "highly productive low intertidal surface area" habitat between 0.6 m below MLLW and 0.6 m above was observed, as well as an estimated 17% decrease in area of eelgrass beds. A decrease in the amount of mesohaline mixing habitat was reported. Habitat losses in the Skokomish River basin are similar to those reported in other regions containing larger river basins experiencing water withdrawals of the same scale.

Alteration of flows through major rivers

Due to two dams on the Skokomish River, 40% of the annual average freshwater flow is diverted for power production and never reaches the delta (Jay and Simenstad 1996). Freshwater flow from the North Fork Skokomish River is mostly re-routed and does not contribute to mainstem flow contributions to the estuary (USFWS 2004). Sediment transport "is a critical link between fluvial alterations and the remote downstream, estuarine consequences thereof" (Jay and Simenstad 1996). Changes in habitat function and physical processes must be considered when evaluating estuarine effects of human-caused modifications.

Both dams have had lasting impacts on water quality and connectivity in the Skokomish River system and Hood Canal (USFWS 2004). Sediment transport capacity, available habitat, and channel capacity has been reduced, and flooding has become more frequent (USFWS 2004).

Modification of shorelines by armoring, overwater structures and loss of riparian vegetation/LWD

The projected population growth in Mason, Kitsap and Jefferson counties between 2000-2025 is 52% (25, 683 people), 43% (99,602 people), and 55% (14,508 people) respectively (PSAT 2004). In this sub-basin, shoreline armoring occurs along 63 miles (32%) of the shoreline. Over 40 miles of shoreline are classified as 100% armored. Over 107 miles are classified as 0% armored. The total number of overwater structures is 1,448, consisting of ramps (159), piers and docks (264), small slips (1,017) and large slips (8). Overwater structure are concentrated in the southern most region of Hood Canal. Railroads are not present.

Contamination of nearshore and marine resources

Regions with 15% or greater impervious surface area occur in Mason County near the terminus of Hood Canal, and sporadically along the western shoreline of Hood Canal north into Dabob Bay (PSAT 2004). In this sub-basin, nitrogen and organic material from various sources contribute to eutrophication, promoting excessive and rapid algal growth. Upon decomposition of algae, microorganisms can deplete the available oxygen in surrounding waters (Fagergren et al, 2004). Six primary categories of "human-influenced nitrogen sources" have been identified, totaling between 86 and 319 tons per year: Human sewage from onsite systems (39-241 tons); Stormwater runoff (12-24 tons, including lawn fertilizers); Chum salmon carcass disposal (16-24 tons); Agriculture – animal waste (18-22 tons); Forestry (0.5-5 tons); and Discharges from point sources (0.3-3 tons) (Fagergren et al, 2004).

Geographic source locations for each of the categories of nitrogen are as follows (from Fagergren et al, 2004): Human sewage (onsite systems) and stormwater runoff sources correspond to the populated regions of Hood Canal (Figure E-7.2). Chum salmon carcass deposition occurs primarily in the Skokomish River estuary. Agriculture (animal) waste occurs primarily in the Skokomish and Union watersheds. Fertilization in forestry practices occur in the southern half of Hood Canal on private forestlands, as well as on USFS lands throughout the sub-basin. Discharges from point sources occur in various forms and are located throughout Hood Canal. The 303D points are concentrated in the area from Union to Belfair; general industrial sources are concentrated in the Belfair region and Quilcene Bay, and a few other locations spread around the Canal.

Alteration of biological populations and communities

Nine hatcheries operate in this sub-basin (State, Federal, Tribal) as well as 12 small private salmon production operations (USFWS 2004).

Transformation of land cover and hydrologic function of small marine discharges via urbanization

Figure E-7.4 provides a list of pocket estuaries and stressors noted from review of oblique aerial photos.

Transformation of habitat types and features via colonization by invasive plants

Spartina spp are not found in this sub-basin. However, 45% of the shoreline (92 miles) contains *Sargassum muticum*, which may be patchy or continuous.

B. Evaluation

In this section we list goals and evaluate the level of realized function for natal and non-natal Chinook, summer chum, and bull trout. From this we then list each of the proposed protection and restoration actions for this sub-basin, and describe the benefits to natal Chinook, non-natal Chinook, and summer chum and bull trout (if any).

Goals for listed salmon and bull trout whose natal streams are in this sub-basin

a) Provide early marine support for all four life history types (fry migrants, delta fry, parr migrants, yearlings) of the Skokomish Chinook salmon population emanating from this sub-basin. Provide early marine support for Chinook populations emanating from other estuaries (e.g., Dosewallips, Duckabush, Hamma Hamma, and others – See list in 1 a) and b))
b) Provide support for sub-adult and adult Chinook salmon populations utilizing habitats within this sub-basin as a migratory corridor and grazing area.
c) Provide early marine support for the six Hood Canal/Eastern Strait of Juan de Fuca Summer chum salmon populations emanating from this sub-basin
d) Provide marine support for sub-adult and adult anadromous bull trout populations within the Skokomish core area in this sub-basin
e) Provide for connectivity of habitats; also, adequate prey resources, marine foraging areas, and migratory corridors for juvenile, sub-adult and adult Chinook, Hood Canal/Eastern Strait of Juan de Fuca Summer chum, and bull trout.

Goals for listed salmon and bull trout whose natal streams area outside this sub-basin

a) Provide for some non-natal Chinook use: Elwha and Dungeness fish are known to use this sub-basin.
b) Provide support for all neighboring Puget Sound populations (juveniles, sub-adults, and adults) that utilize nearshore and marine regions of this sub-basin as a migratory corridor.

Realized function for listed salmon and bull trout

Fry migrant Chinook – Fry migrants from the Skokomish independent Chinook salmon population can derive function from the mostly low wave energy shorelines and nine pocket estuaries within five and ten miles of the Skokomish natal estuary (Figure E-7.2). Many of the pocket estuaries provide the opportunity to rear, osmoregulate and seek refuge in the shallow water, low-velocity habitats, however nearly half of these pocket estuaries are also at risk of losing this ability due to the presence of stressors (see Figure E-7.4). The majority of properly functioning pocket estuaries occur well outside and to the north of the 10-mile buffer of the Skokomish delta. Again, connectivity between habitat types and landscape classes, including intact freshwater "lenses" (or bands) along shorelines, is essential for small-sized fry migrants emerging from the Skokomish delta in search of rearing and refuge locations, and satisfying osmoregulatory requirements.

In addition, water quality (dissolved oxygen), water quantity (Cushman dam) and shoreline armoring/development are three factors that have the potential to impact the fry migrant's ability to emigrate to desired habitats outside the Skokomish estuary.

Delta fry Chinook – The net loss of intertidal wetlands within the Skokomish delta from historic conditions is relatively small (0.27 mi^2 or 124 acres) (Bortleson et al., 1980). Consequently, the opportunity for Chinook salmon delta fry to access delta habitat is available, and scheduled to improve with the advent of some dike removal to expose additional delta habitat. The Skokomish estuary has the potential to produce large numbers of Chinook salmon delta fry, as well as Hood Canal/Eastern Strait of Juan de Fuca Summer chum salmon (discussed below). Reversing the persistent poor water quality conditions in south Hood Canal (e.g., dissolved oxygen) is a key step to salmon recovery in this sub-basin. The water quantity issues and shoreline armoring/development described above also impact this life history type. Connectivity of habitat types and landscape classes is again, critical to delta fry.

Parr migrant Chinook – Many of the Puget Sound Chinook salmon migrate to the ocean as sub-yearlings (Myers et. al., 1998), and on average this life history type is the most abundant in Puget Sound. The opportunity exists for parr migrants from the Skokomish Chinook salmon population, and from populations in other estuaries (e.g., Hamma Hamma, Duckabush, Dosewallips) as well as Hood Canal/Eastern Strait of Juan de Fuca Summer chum salmon to derive function from habitats nested within shorelines. The numerous bays and eelgrass bands in this sub-basin may provide a valuable resource to this life history type as they emigrate north toward the Strait of Juan de Fuca.

Yearling Chinook – Any reduction in capacity as a result of non-support of the other life history types (i.e., primarily parr migrants) within this sub-basin will negatively affect yearling migrants. Connectivity between habitat types and landscape classes is very important to yearlings from the Skokomish Chinook salmon population and the Hood Canal/Eastern Strait of Juan de Fuca Summer chum populations (discussed below), as well as other populations moving about broadly within Puget Sound. Yearling migrants will be exposed to the same types of stressors and ramifications as described in the other sections above. Yearling migrants can derive functions (e.g., foraging, refuge, migratory pathway) from available nearshore habitats as described above. Of particular concern is the poor water quality plaguing this sub-basin, and while outmigrating yearlings may be less impacted than returning adults (or sub-adults) due to the timing of low D.O. events, this life history type is nonetheless at risk of ever increasing D.O. problems.

Sub-adult and adult Chinook – Sub-adult, and especially adult Chinook are likely to face an increasing problem when returning to Hood Canal to spawn in freshwater systems in the fall. This time of year corresponds annually to the lowest D.O. levels in southern Hood Canal, and as mentioned in earlier sections, the spatial and temporal trends are increasing northward and occurring earlier in the year. Other factors related to depressed D.O. conditions, and potentially impacting sub-adults and returning adults focus on the food web: available prey items, contaminated food chain, among others.

Listed summer chum – Six natal populations emanate from this sub-basin. As young fry in Hood Canal, summer chum remain close to shore in shallow surface waters while rearing in estuarine habitats, but after a short period of time larger fish can move offshore into open marine waters, even crossing Hood Canal (Simenstad 2000a). Smaller estuaries other than the natal estuaries listed in 1 b) are important to juvenile chum, termed subestuaries by Simenstad (2000a), but pocket estuaries in this analysis. These estuaries, or "patches" occur at irregular intervals along the shoreline of Hood Canal, and some of these can be viewed in Figure E-7.4. Eelgrass is very important as habitat for juvenile summer chum and it is probable that eelgrass is the principal migratory corridor linking estuaries at the estuarine landscape in Hood Canal (Simenstad 2000a). Interruption of contiguous migratory corridors, in this case eelgrass bands, may negatively impact juvenile chum salmon. Several activities contribute to this interruption, including armoring, diking, and overwater structures.

Dabob Bay is thought to be especially important summer chum salmon, and the central and northern regions of Hood Canal yield the majority of pocket estuaries. Returning adult chum salmon will most likely experience similar issues with the depressed D.O. levels, as do adult Chinook.

We refer the reader to the Hood Canal/Eastern Strait of Juan de Fuca Summer chum recovery plan at this web site address **http://wdfw.wa.gov/fish/chum/chum-5b.htm** for more information.

Anadromous Bull Trout – The bull trout population from the Skokomish is depressed and at risk of extirpation as a result of reduced numbers and fragmentation (USFWS 2004). Due to the Skokomish dams, the altered sediment size and patterns has increased erosion on the outer delta and increased deposition on the inner edge of the delta (USFWS 2004). As a result, the biological productivity of the intertidal zone within the estuary has been reduced, as has the eelgrass area of which herring require for spawning (USFWS 2004). Herring are an important prey item for bull trout, and because of the issues described above, foraging opportunities have been reduced in the Skokomish estuary (USFWS 2004). Furthermore, the dams on the Skokomish River have had effects that have reduced the available spawning and rearing habitat (USFWS 2004).

Table 6-14. Recommended protection actions for Hood Canal

Protection Action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Aggressive protect areas, especially shallow water/low gradient habitats and pocket estuaries, within 5 miles of the Skokomish delta (and the deltas of the composite populations from the Dosewallips, Duckabush and Hamma Hamma).	Sustained feeding, growth, refuge, osmoregulation and migration functions for Skokomish and composite central Hood Canal populations	Sustained feeding, refuge and migration functions for other populations	Sustained feeding, growth, refuge, osmoregulation functions for summer chum and anadromous bull trout and other species
Protect small freshwater tributary regions	Sustained feeding, osmoregulation and refuge functions for Hood Canal populations	Sustained feeding, osmoregulation and refuge functions for other Puget Sound populations	Sustained feeding, osmoregulation and refuge functions for summer chum and anadromous bull trout
Protect against catastrophic events	Sustained feeding, growth and migration functions for Hood Canal populations	Sustained migration functions for other populations	Sustained feeding, growth and migration functions for summer chum and anadromous bull trout
Aggressively protect functioning drift cells and feeder bluffs that support eelgrass bands and depositional features along the entire eastern shoreline and the western shoreline north of Point Whitney, including Dabob and Quilcene bays. Counties should designate these shorelines for the highest level of protection within shoreline master programs and critical areas ordinances and pass strong policies limiting increased armoring of these shorelines and offering landowner incentives for protection.	Sustained feeding, growth, refuge and migration functions for Hood Canal populations	Sustained feeding, growth, refuge and migration functions for other populations	Sustained feeding, growth, refuge and migration functions for summer chum and anadromous bull trout

Table 6-15. Recommended improvement actions for Hood Canal

Improvement Action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Achieve and maintain adequate dissolved oxygen levels, including avoidance of further stormwater loadings and NPDES discharge loadings. Consider wastewater reclamation and reuse retrofits for all sewage discharges from wastewater plants into lower Hood Canal	Decreased risk of hypoxia-induced mortality	Decreased risk of hypoxia-induced mortality	Decreased risk of hypoxia-induced mortality
Aggressively promote shellfish environmental codes of practice	Improved feeding, refuge and migration functions for Hood Canal populations	Improved feeding, refuge and migration functions for other populations	Improved feeding, refuge and migration functions for summer chum and anadromous bull trout
Restore the Skokomish River delta by removing dikes, insuring adequate overbank flooding within the floodplain and adequate freshwater inflow from the watershed	Improved feeding, growth, refuge, osmoregulation and migration functions for Skokomish and composite central Hood Canal populations	Improved feeding, refuge and migration functions for other populations	Improved feeding, growth, refuge, osmoregulation functions for summer chum and anadromous bull trout and other species
Aggressive restore areas, especially shallow water/low gradient habitats and pocket estuaries, within 5 miles of the Skokomish delta (and the deltas of the composite populations from the Dosewallips, Duckabush and Hamma Hamma)	Improved feeding, growth, refuge, osmoregulation and migration functions for Skokomish and composite central Hood Canal populations	Improved feeding, refuge and migration functions for other populations	Improved feeding, growth, refuge, osmoregulation functions for summer chum and anadromous bull trout and other species
Increase tidal prism and estuarine connectivity (i.e., all distributaries) at all Highway 101 river crossings to benefit natal and non-natal populations of Chinook and Hood Canal/Eastern Strait of Juan de Fuca Summer chum salmon.	Improved feeding, growth, refuge, osmoregulation and migration functions for Skokomish and composite central Hood Canal populations	Improved feeding, refuge and migration functions for other populations	Improved feeding, growth, refuge, osmoregulation functions for summer chum and anadromous bull trout and other species

6.8 Central Puget Sound

In this section we assess salmon and bull trout use, food web and ecological conditions, landscape conditions, and threats.

1. Salmon Use

Chinook

NOAA-TRT has identified five independent populations emanating from this sub-basin:
- Lake Washington
- Cedar
- Green
- White
- Puyallup

This sub-basin provides direct support to meeting the Chinook ESU criteria by supporting rearing of juveniles, sub adults, and adults of many populations from almost all geographic regions of origin.

a) Juvenile
- Juvenile Chinook salmon from each of the five natal populations, as well as non-natal populations from throughout Puget Sound, utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor (juvenile salmon functions).
- Juvenile Chinook salmon primarily use the Green, Puyallup and Lake Washington areas as a migratory corridor – a link from upper watersheds to Puget Sound.
- Non-natal populations likely derive some function from the smaller freshwater tributaries within this basin.

b) Adult
- Sub-adult and adult salmon from the five natal populations utilize habitats within this sub-basin as a migratory corridor and grazing area.
- Adult Chinook salmon from non-natal populations also utilize this sub-basin

Other Listed Species (not comprehensively reviewed or assessed for this sub-basin)

- Chum salmon: Natal populations of the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU do not exist in this sub-basin. Non-natal use may occur, but it is not known for certain. Non-natal use by early migrant chum salmon from Northern Hood Canal Rivers may extend south into this sub-basin (i.e., Kingston area).
- Bull trout (anadromous): The Puget Sound Management Unit contains two preliminary core areas (Puyallup, Chester Morse) in this sub-basin. The Puyallup watershed is critical for sustaining the distribution of the anadromous bull trout life history trait within Puget Sound because it is the only main watershed in south Puget Sound supporting this life history type. This core area contains an estimated 5 local populations, less than 1000

> adult fish (estimated) and an unknown population trend (population numbers generally low) (USFWS 2004).

2. Ecological and Landscape Conditions

Food Web, Ecological Conditions

The Central Puget Sound sub-basin is the most industrialized and populated sub-basin in Puget Sound. The three main natal Chinook estuaries on the eastern shore of this region, Puyallup River at Commencement Bay, Duwamish River at Elliot Bay, and "Salmon Bay" at Shilshole Bay draining Lake Washington, are highly developed. Many of the smaller estuaries and pocket estuaries, as well as shorelines are also developed to varying degrees. As a result, populations of Chinook (and particular life history types) have been impacted more so than populations from other sub-basins.

Portions of this sub-basin exhibit poor water quality, and if not addressed or corrected, may continue to negatively affect the ecology of this sub-basin. Toxic contaminants such as PCBs and PBDEs (and others) are polluting the food web of Puget Sound, particularly the central and south sound basins (three sub-basins: central Puget Sound, Carr-Nisqually, south Puget Sound). Natal Chinook salmon populations from the two basins as well as a primary salmon prey (i.e., Pacific herring) appear to be contaminated with toxics (see following sections for more detail). These "resident" salmon (i.e., natal populations) exhibit greater concentrations of toxics when compared to migratory salmon (i.e., non-natal populations) passing through each sub-basin.

Quartermaster Harbor supports forage fish (e.g., herring) spawning functions, and forage fish are an important prey resource for natal and non-natal salmon populations. A recent oil spill in the Dalcos Passage region spread to Quartermaster Harbor.

Landscape Conditions

The Central Puget Sound sub-basin is the most industrialized and populated sub-basin in Puget Sound, yet it still maintains a fairly high level of ecological function within some ecosystem components. Below are excerpts from the Executive Summary of King County's State of the Nearshore Report for Water Resource Inventory Areas 8 and 9, which make up the bulk of the main basin of Puget Sound.

> Eelgrass forms small patches to large meadows in the low intertidal and shallow subtidal zone of Puget Sound, covering about 57 percent of the shoreline of WRIA 8 and 62 percent of WRIA 9. Kelps occur in small patches to large forests throughout the study area, covering 12 percent of the shoreline in WRIA 8 and 7 percent of WRIA 9, including 6.4 percent within Elliott Bay. Six percent of the shoreline in WRIA 8 and 29.7 percent of the shoreline in WRIA 9 is composed of flats as defined by the ShoreZone database, which does not include lower tidal flats. Over the past century, 97 percent of the shallows and flats in the Duwamish estuary and Elliott Bay have been lost due to dredge and fill operations for urban and industrial development. Although the entire delta was filled in, much of the subsequent shoreline armoring is present in the upper intertidal

zone, and gently sloping mud and sandflats exist in the lower intertidal and subtidal zones. Shoreline armoring, dredging, and filling have probably caused loss of flats in other parts of the study area, as well. Historical filling, diking, armoring, and other human intrusions have eliminated all but a few small tidal marshes in the study area. Dramatic reductions occurred in the Duwamish estuary, where over 1,170 acres of tidal mash was eliminated early in the century. The largest remaining tidal marsh system in WRIAs 8 and 9 is Kellogg Island, within the Duwamish estuary. Most of the shoreline of Puget Sound is composed of gravel, cobble, sand, or silt beaches. Beaches are generally distinguished from flats by their steeper grade, but generally support similar functions. Puget Sound beaches often transition to sandflats at about MLLW. Similar to the use of flats, juvenile salmonids rely on beach environments for foraging and refuge before migrating to deeper water. Adult bull trout and cutthroat trout also forage seasonally in shallow beach habitats at high tides. Beaches and backshore areas can be highly productive; shellfish production is commonly very high on cobble and gravel beaches where deposition includes organic matter. (King County DNR, 2001).

Figures E-8.1 through E-8.5 in Appendix E depict additional information about the landscape condition in central Puget Sound.

Overall area

- Total area (deep-water plus nearshore) is 192,511 acres (300.8 square miles)
- Deep-water portion (marine waters landscape class) comprises 158,655 acres (247.9 square miles), or 82% of the total sub-basin area.

Nearshore area

- Nearshore portion comprises 33,856 acres (52.9 square miles), or 18% of the total sub-basin area. As part of the nearshore, the Puyallup, Duwamish and “Salmon Bay” deltas are natal deltas for the independent Chinook populations listed above, comprising 3.22 square miles (6%) of the total nearshore area within this sub-basin.
- Nearshore area within this sub-basin is 8% of the nearshore area of the entire Puget Sound basin.
- Contains 308 miles of shoreline (beaches landscape class).
- The “key” bays (landscape class) identified in this sub-basin are Shilshole Bay, Elliot Bay, Commencement Bay, Gig Harbor, Quartermaster Harbor, Clam Bay, Blakely Harbor, Eagle Harbor, Murden Cove, Port Madison, Miller Bay, Appletree Cove, and Cultus Bay.
- Sixty-six linear miles (21%) of the shoreline is designated as marine riparian (defined as the estimated area of length overhanging the intertidal zone).
- In this sub-basin, 50% of the shoreline (154 linear miles) has eelgrass (*Zostera marina* and *Z. japonica*); may be patchy or continuous.
- In this sub-basin, 10% of the shoreline (32 linear miles) has floating kelp; may be patchy or continuous. Also in this sub-basin, 23% of the shoreline (71 linear miles) has non-floating kelp; may be patchy or continuous.

Pocket Estuary Analysis

We identified 37 pocket estuaries in this sub-basin: most of these are located on the western shorelines of this sub-basin; only a few are located on the east shore of the basin and most of these are north of Edmonds.

- Freshwater sources were observed in nearly two-thirds of the pocket estuaries,
- Based on the assumptions listed in Appendix B, all three of the Chinook functions (feeding, osmoregulation and refuge) were estimated were estimated to occur in 12 of the 37 pocket estuaries. Most of the remaining pocket estuaries were estimated to have two of the three Chinook functions,
- Fifteen pocket estuaries were estimated to be *properly functioning*. Four pocket estuaries were estimated to be *not properly functioning*. The remaining 18 pocket estuaries were recorded as *at risk*.

Drift Cell Analysis

A drift cell characterization developed for this sub-basin is presented in Appendix E, Figure E-8.5 and subsequent text. Highlights of recommendations for protection and restoration are included in Tables 6-16 and 6-17.

Threats/stressors

For a detailed listing of threats and stressors identified for Central Puget Sound, refer to King County's State of the Nearshore Report, 2001.
http://dnr.metrokc.gov/wlr/watersheds/puget/nearshore/sonr.htm

Loss and/or simplification of delta and delta wetlands

Comparison of historical wetland area and wetland area reported in Bortleson et al. (1980) revealed that for the Duwamish delta, the estimate area of subaerial wetlands decreased from historical to date of survey in 1980 from 1.0 to 0.01 square miles (decreased by 0.99 square miles). The estimated area of intertidal wetlands decreased from historical to date of survey in 1980 from 3.28 to nearly 0 square miles (decreased by as much as 3.28 square miles). Extensive dredge and fill operations have resulting in a nearly 100% loss of intertidal wetlands from historic conditions in the Duwamish delta is nearly 2,100 acres.

Comparison of historical wetland area and wetland area reported in Bortleson et al. (1980) revealed that for the Puyallup delta, the estimate area of subaerial wetlands decreased from historical to date of survey in 1980 from 3.86 to nearly 0 square miles (decreased by as much as 3.86 square miles). The estimated area of intertidal wetlands decreased from historical to date of survey in 1980 from 2.86 to 0.04 square miles (decreased by 2.82 square miles). Extensive dredge and fill operations have resulting in a 98% loss of intertidal wetlands (1,804 acres) from historic conditions in the Puyallup delta.

Alteration of flows through major rivers

In the Green/Duwamish River drainage a re-distribution of flows has occurred. Prior to 1900, several rivers drained nearly 1600 square miles before forming the Duwamish River and ultimately emptying into Elliot Bay (King County, 2002). By 1916, the drainage network was substantially altered, with three rivers re-routed from the Green/Duwamish system and a nearly one-third reduction in the total drainage area (King County, 2002) (Figure 4-6). In addition, a diversion dam and flood control dam blocking upstream fish passage was erected on the upper Green River and a hatchery opened on the same river in 1901-02. The lower Green/Duwamish River was dredged, channelized, shortened and straightened to better facilitate navigation (King County, 2002).

Modification of shorelines by armoring, overwater structures and loss of riparian vegetation/LWD

The projected population growth in King, Snohomish, and Pierce counties between 2000-2025 is 20% (355,356 people), 53% (323,290 people), and 34% (241,337 people) respectively (PSAT 2004). In this sub-basin, shoreline armoring occurs along nearly 179 miles (58%) of the shoreline. Over 136 miles of shoreline are classified as 100% armored. Eighty-seven miles are classified as 0% armored. The total number of overwater structures is 10,448, consisting of ramps (251), piers and docks (838), small slips (9,032) and large slips (327). Overwater structure are observed in greater concentrations in Commencement Bay and Tacoma, Duwamish waterway and Elliot Bay. These structures are also evident along much of the eastern shoreline of the sub-basin, as well as Vashon and Maury Island, eastern half of Bainbridge Island, and part of Colvos Passage. Within 300 feet of shore railroad grades occur along 18.9 miles, following the shoreline in the Tacoma area, and from Ballard north to Mukilteo.

Contamination of nearshore and marine resources

Regions with 15% or greater impervious surface are found along most of the eastern shore of this sub-basin (PSAT 2004).

Sediment samples analyzed from 1997-1999 reveal the central Puget Sound region to have the greatest degree of degraded sediments (PSWQAT 2002a). Chemical concentrations in Puget Sound sediments are typically greater in urban/industrialized regions, such as in Elliot Bay and Commencement Bay (PSWQAT 2002a). 4.6 percent of the area of central Puget Sound is contaminated about state sediment quality standards and 2.6% of the area exceeds the cleanup screening levels.

See Figure E-8.3 for a depiction of the distribution of water quality impairments in central Puget Sound.

Alteration of biological populations and communities

Pacific herring have been found to be “3 to 11 times more contaminated with PCBs in central and south Puget Sound than the Strait of Georgia” (WDFW, unpublished data). These WDFW results from 2004 are similar to those reported in 1999 and 2000 in PSWQAT (2002a), where body burdens of PCBs were higher in Pacific herring from the central basin (Port Orchard) and southern Puget Sound basin (Squaxin Pass) than Pacific herring from northern Puget Sound and the Strait of Georgia.

There are approximately 30 hatcheries releasing various species of salmonids into the main basin of Puget Sound, the highest concentration of hatcheries of any sub-basin. This may affect community structure at certain times of the year, especially if hatchery releases are not appropriately timed to avoid over-utilization of available prey resources or predation of wild fish. Because of poor water quality, there are no commercial shellfish aquaculture operations in the Main Basin, however, there are several floating net pen aquaculture facilities. Overharvest of fisheries species in the past, continued recreational fishing pressure, loss of critical habitats and poor water quality have potentially greatly altered biological populations and communities within the main basin but comparative studies with other sub-basins in Puget Sound have not been conducted.

Specific hatchery reform recommendations for this region have been formulated by the Hatchery Scientific Review Group available at the following websites.
http://www.lltk.org/pdf/HSRG_Recommendations_February_2002.pdf
http://www.lltk.org/pdf/HSRG_Recommendations_March_2003.pdf

Transformation of land cover and hydrologic function of small marine drainages via urbanization

In many cases, the historic pocket estuaries of the main basin have been completely filled or drained for development. The University of Washington River History Project in cooperation with Washington Department of Natural Resources and the Puget Sound Nearshore Ecosystem Restoration Project, is conducting an analysis of central Puget Sound shorelines using historical maps and data sets to ascertain how many small marine discharges and their associated marsh and mudflat features may have been lost in the Main Basin over the last 150 years. .

Figure E-8.4 lists of pocket estuaries we identified in central Puget Sound and evaluates the stressors on these pocket estuaries based on our review of oblique aerial photos.

Transformation of habitat types and features via colonization by invasive plants

One percent of the shoreline (4 miles) contains *Spartina spp*; may be patchy or continuous. 26% of the shoreline (81 miles) contains *Sargassum muticum*; may be patchy or continuous. Because of the proximity of these shorelines to developed urban and suburban areas, the presence of invasive escaped garden plants is high even in relatively undisturbed parkland. Scotch broom, English ivy and Japanese knotweed are particularly abundant along shoreline parks and forested residential properties.

B. Evaluation

In this section we list goals and evaluate the level of realized function for natal and non-natal Chinook, summer chum, and bull trout. From this we then list each of the proposed protection and restoration actions for this sub-basin, and describe the benefits to natal Chinook, non-natal Chinook, and summer chum and bull trout (if any).

Goals for listed salmon and bull trout whose natal streams are in this sub-basin

a) Provide early marine support for available life history types of the Chinook populations emanating from this sub-basin,
b) If fry migrant and delta fry life history types from the Green River population are functionally extinct, these life history types will need to come from outside this sub-basin.
c) Provide support for sub-adult and adult Chinook salmon populations who utilize habitats within this sub-basin as a migratory corridor and grazing area,
d) Provide marine support for sub-adult and adult anadromous bull trout populations (5) within the two core areas in this sub-basin (Puyallup, Chester Morse).
e) Provide for connectivity of habitats; also, adequate prey resources, marine foraging areas, and migratory corridors for juvenile, sub-adult and adult Chinook, and bull trout.

Goals for listed salmon and bull trout whose natal streams are outside this sub-basin.

a) Provide support for all neighboring Puget Sound populations (juveniles, sub-adults, and adults) that utilize nearshore and marine regions of this sub-basin as a migratory corridor.
b) Provide support functions in the northern portion of this sub-basin for early migrant Hood Canal/Eastern Strait of Juan de Fuca Summer Chum, if used.

Realized function for listed salmon and bull trout

Fry migrant Chinook – The fry migrant and delta fry life history types may be "functionally extinct," from an ESU perspective, in the central sub-basin. Independent populations of Chinook salmon from the Green, Puyallup and Lake Washington are at very high risk. Only five pocket estuaries are identified along the extensively armored and expansive, highly urbanized eastern shoreline of this sub-basin (Figure E-8.2 in Appendix E). Just two of the pocket estuaries are estimated to be properly functioning. The remaining pocket estuaries are located on the western shoreline of this sub-basin, opposite the three highly developed natal deltas supporting five independent populations of Chinook salmon. If this sub-basin does produce the fry migrant life history type, there is little opportunity or capacity to access or utilize any shallow water, low-velocity habitats along the same shoreline as the natal deltas. Instead, the small fish may need to traverse across the open waters to access shallow, low velocity areas and pocket estuaries on the western shoreline. There are shallow, protected shorelines within reach of Central Sound rivers where small Chinook can be found along Bainbridge Island shorelines in the spring. While these habitats are within five or ten miles of each natal estuary (Figure E-8.2), it is not known if remnant fry migrant life history types readily exploit habitats on western shores.

In addition, available fry migrants must contend with a host of issues, each affecting the ability to access and derive function from suitable habitats (i.e., connectivity between natal deltas and landscape classes and habitat types). For example, water quantity (reduced due to dams, diversions, developed stream mouths; reduction/loss of seeps and groundwater recharge), water quality (elevated temperature and reduced dissolved oxygen), pollution (chemicals and wastewater discharges [Figure E-8.3], and elevated body burdens of toxic contaminants such as PCBs and PBDEs in salmon within this sub-basin [WDFW, unpublished data]) and physical attributes (extensively armored eastern shoreline [bulkheads, railroads], clearing and grading of marine riparian vegetation). It is not known if restoration activities would benefit this marginally existent life history type.

Delta fry Chinook – The natal estuaries have been substantially altered from historic conditions, and as stated above, it is believed the delta fry life history type may be "functionally extinct." See the delta loss information (Bortleson et al, 1980) presented in the stressor section, above (e.g., loss of delta and delta wetlands). Consequently, the opportunity and capacity for delta fry to utilize habitats within the three estuaries is nearly eliminated. Connectivity between habitat types within the estuary/shorelines and landscape classes is essential for small-sized delta fry emigrating distances to and within this sub-basin. Furthermore, the conditions and stressors described above in the fry migrant section also impact any remnant natal delta fry. In general, this sub-basin lacks delta fry life history types from each of the five populations.

Simenstad (2000) discussed the ability of Commencement Bay and the Puyallup delta habitats to support juvenile salmon. His assessment shows that present-day delta habitats are smaller, extremely fragmented with little or no connectivity, and with numerous stressors impacting the region. Puyallup River freshwater contributions still exist, but lateral water movement within the delta, as well delivery of sediments and organic materials, is not occurring. River flow and sediment contributions fail to extend out into the Bay very far, and therefore sediments cannot adequately replenish nearshore, intertidal and/or shallow subtidal habitats. As a result, the utilization of habitats by one or more of the four life history types is limited. There is little opportunity for delta fry, for example, to derive important rearing and physiological transition functions from the Puyallup delta because these fish, and all juvenile salmon, are thrust into the Commencement Bay and forced to osmoregulate in higher salinities (brackish) than if allowed to osmoregulate in the preferred shallow water, low-velocity regions typical of other estuaries (e.g., Nisqually). It should be noted that juvenile salmon (such as delta fry) are capable of exploiting any shallow water, low-velocity regions, and in fact continue to do so wherever available in the Puyallup delta. Finally, restoration opportunities do exist in this highly urbanized delta (e.g., diversion of some Puyallup River flow through Hylebos waterway to encourage build up of delta).

Parr migrant Chinook – Many of the Puget Sound Chinook salmon migrate to the ocean as sub-yearlings (Myers et. al., 1998), and on average this life history type is the most abundant in Puget Sound. The opportunity exists for larger-sized parr migrants from natal Chinook populations, as well as non-natal populations from throughout Puget Sound to utilize shallow water, low-velocity habitats within the nearshore (e.g., estuaries, pocket estuaries and shorelines), of primarily the western shorelines of this sub-basin. Numerous *properly functioning* (and *at risk*) pocket estuaries are located on Bainbridge, Vashon and Maury Islands, characterized by much less armoring than the eastern shoreline. Non-natal parr migrants moving north from the southern sub-basins, and south out of the Whidbey sub-basin can utilize these nearshore habitats. In addition, juveniles from the Hood Canal/Eastern Strait of Juan de Fuca Summer chum ESU may frequent and utilize habitats within the northern section of this sub-basin. This is not known for certain.

As discussed in the above sections, numerous conditions and stressors affect the natal estuaries, other estuaries, and eastern shoreline of the sub-basin. These also impact natal and non-natal parr migrants moving throughout the Central Sound sub-basin. Connectivity between habitat types and landscape classes is essential to this life history type. Any type of catastrophic event (e.g., oil spill) would likely affect many of the ESA-listed salmon populations within Puget Sound. Guarding against such an event is a critical step to safeguarding populations as they emigrate to the Pacific Ocean.

Yearling Chinook – Any reduction in capacity as a result of non-support of the other life history types (i.e., primarily parr migrants) within this sub-basin will negatively affect yearling migrants. Connectivity between habitat types and landscape classes is also important to yearlings from the three natal populations, and other populations moving about broadly within Puget Sound. Yearling migrants will be exposed to the same types of stressors and ramifications as described in the other sections above. Yearling migrants can derive functions (e.g., foraging, refuge, migratory pathway) from available nearshore habitats as described above. Of special concern are the toxic contaminants polluting the food web in the three southern sub-basins and the body burden effects on salmon. In addition, the forage fish population in Quartermaster Harbor is an important prey species for natal and non-natal yearling life history types, as well as to the smaller-sized juvenile salmon (e.g., parr migrants).

Sub-adult and adult Chinook – Larger fish migrating through this sub-basin must contend with several issues, including toxic contaminants in the food chain, sediment contamination in several urban estuaries, and the potential for oil spills. Researchers from WDFW have documented that, in general, Chinook salmon living in or migrating through Puget Sound (specifically in central and south sound) are more contaminated with PCBs than stocks outside of Puget Sound (e.g., Columbia River, WA coast). See Figure 4.7 in Section 4. Residence time in the central and southern Puget Sound basins is suspected as a "primary predictor of PCB concentration in Chinook salmon" and as such, those salmon spending the greatest amount of time in central and south sound exhibit the greatest PCB concentrations (WDFW, unpublished data) (Figure 4-8). Another toxic contaminant of concern in Puget Sound is PBDEs, a common chemical that, like PCBs, are found in greater concentrations in resident Chinook salmon versus migratory Chinook salmon.

Listed summer chum – We hypothesize that Hood Canal/Eastern Strait of Juan de Fuca summer chum salmon may use the northern portion of this sub-basin, but to what degree is not known.

Anadromous bull trout – Of the two core areas, the Puyallup watershed is critical for sustaining the distribution of the anadromous bull trout life history trait within Puget Sound because it is the only main watershed in south Puget Sound supporting this life history type, and is the southernmost population of bull trout (USFWS 2004). Anadromous bull trout use the Puyallup and White River, and are thought to use habitats in Commencement Bay and other nearshore shorelines (USFWS 2004). Extensive development in the Commencement Bay region is likely impacting bull trout. Furthermore, as with yearling Chinook, and sub-adult and adult Chinook, bull trout may be impacted by contamination of sediments and prey items. Also, the loss of LWD in lower reaches of large rivers and estuaries may have reduced habitat complexity.

Table 6-16. Recommended protection actions for central Puget Sound

Protection action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Protect smaller freshwater tributaries	Sustained feeding, growth, osmoregulation and refuge functions	Sustained feeding, growth and refuge functions	Sustained feeding, growth, osmoregulation and refuge functions for anadromous bull trout, summer chum and other species
Protect water quality, especially temperature and dissolved oxygen– must ensure appropriate levels of each are available to any and all life history types utilizing this sub-basin.	Sustained growth and reduced mortality	Sustained growth and reduced mortality	Sustained growth and reduced mortality of anadromous bull trout, summer chum and other species
Protect the forage fish spawning areas in Quartermaster Harbor	Sustained feeding function	Sustained feeding function	Sustained feeding function for anadromous bull trout and other species
Protect all remaining functional shoreline features on Vashon-Maury Island from further degradation. The relative importance of low levels of shoreline development in this heavily armored sub-basin cannot be overestimated.	Sustained feeding, growth, refuge, migration functions, especially for Puyallup and Duwamish populations	Sustained feeding, growth, refuge, migration functions	Sustained feeding, growth, refuge, migration functions for anadromous bull trout and other species
Protect functioning drift cells, feeder bluffs for their role in supporting eelgrass bands and depositional features along Colvos Passage, Maury Island, Narrows and the shoreline from Kingston to Foulweather Bluff. (Shoreline Protection Target Areas 2, 4, 5, 10, 11, 13, 15, 18, 21, 22 in Figure E-8.5). Designate these shorelines for the highest level of protection within shoreline master programs and critical areas ordinances and pass strong policies limiting increased armoring of these shorelines and support landowner incentive programs for conservation.	Sustained feeding, growth, refuge, migration functions	Sustained feeding, growth, refuge, migration functions for populations from all neighboring sub-basins	Sustained feeding, growth, refuge, migration functions for anadromous bull trout, summer chum and other species
Protect against catastrophic events	Sustained growth and migration functions	Sustained growth and migration functions	Sustained growth and migration functions

Table 6-17. Recommended improvement actions for central Puget Sound

Improvement action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Add enhanced treatment for stormwater discharging directly to Puget Sound to the same standards as for salmon bearing streams.	Improved growth and reduced mortality	Improved growth and reduced mortality	Improved growth and reduced mortality of anadromous bull trout, summer chum and other species
Consider wastewater reclamation and reuse retrofits for all wastewater discharges into the sub-basin, especially new discharges.	Improved growth and reduced mortality	Improved growth and reduced mortality	Improved growth and reduced mortality of anadromous bull trout, summer chum and other species
Complete and implement plans for diverting some Puyallup River flow through the Hylebos to enhance delta structure and processes.	Improved feeding, growth, osmoregulation and refuge functions	Improved feeding, growth and refuge functions, especially for Nisqually population	Improved feeding, growth, osmoregulation and refuge functions for anadromous bull trout and other species
Restore smaller freshwater tributaries.	Improved feeding, growth, osmoregulation and refuge functions	Improved feeding, growth and refuge functions	Improved feeding, growth, osmoregulation and refuge functions for anadromous bull trout, summer chum and other species
Prioritize and implement cleanups of sediment contaminant hot spots and ongoing toxic discharges	Improved growth and reduced mortality via bioaccumulation in the food chain	Improved growth and reduced mortality via bioaccumulation in the food chain	Improved growth and reduced mortality of anadromous bull trout, summer chum and other species
Restore connections between uplands and shorelines by retrofitting Burlington Northern/Santa Fe railroad grade from Golden Gardens to Mukilteo for improved access to blocked pocket estuaries).	Improved feeding, growth, refuge, migration functions	Improved feeding, growth, refuge, migration functions for populations from all neighboring sub-basins	Improved feeding, growth, refuge, migration functions for anadromous bull trout, summer chum and other species
Conduct limited beach nourishment on a periodic basis to mimic the natural sediment transport processes in select sections where corridor functions may be impaired by extensive armoring (Shoreline Restoration Target Areas 12,16, 17, 20,23 in Fig. E-8.5) and seaward of the railroad grade from Golden Gardens to Mukilteo.	Improved feeding, growth, refuge, migration functions	Improved feeding, growth, refuge, migration functions for populations from all neighboring sub-basins	Improved feeding, growth, refuge, migration functions for anadromous bull trout, summer chum and other species
Encourage voluntary re-vegetation of cleared residential shorelines from Alki Point to Brown Point.	Improved feeding, growth, refuge, migration functions	Improved feeding, growth, refuge, migration functions for populations from all neighboring sub-basins	Improved feeding, growth, refuge, migration functions for anadromous bull trout, summer chum and other species
Reform hatchery practices	Improved feeding, growth and survival	Improved feeding and growth	Improved feeding and growth of anadromous bull trout and summer chum

6.9 Port Madison/Sinclair Inlet

A. Assessment

In this section we assess salmon and bull trout use, food web and ecological condition, landscape condition, and threats.

1. Salmon Use

Chinook

NOAA-TRT has identified no independent populations emanating from this sub-basin.

a) Juvenile

- Juvenile Chinook salmon from neighboring populations (e.g., central Puget Sound sub-basin) utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor (juvenile salmon functions). See Figure 3-1 for a list of all Chinook populations. This sub-basin provides direct support to meeting the Chinook ESU criteria by supporting rearing of juveniles of many populations from all five geographic regions of origin, but is likely most importantly for populations from the geographic region it lies within, and adjacent geographic regions of origin.

b) Adult

- Sub-adult and adult salmon from neighboring populations utilize habitats within this sub-basin as a passage corridor and grazing area. This sub-basin provides direct support to meeting the Chinook ESU criteria by supporting rearing of sub adults of many populations from all five geographic regions of origin, but is likely most importantly for populations from the geographic region it lies within, and adjacent geographic regions of origin.

Other Listed Species (not comprehensively reviewed or assessed for this sub-basin)

- Chum salmon: Populations of the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU do not emanate from this sub-basin. It is not known if these populations use this sub-basin
- Bull trout (anadromous): Preliminary core populations within the Puget Sound Management Unit of bull trout do not exist in this sub-basin. It is not known if any anadromous bull trout use this sub-basin.

2. Ecological and Landscape Conditions

Food Web, Ecological Conditions

The Port Madison/Sinclair Inlet sub-basin contains industrialized regions in Dyes Inlet and Sinclair Inlet, and some of the region is experiencing rapid growth. Port Madison supports a herring stock and Dyes Inlet supports a smaller stock, both important prey resource for non-natal Chinook populations.

Overall area

- Total area (deep-water plus nearshore) is 17,728 acres (27.7 square miles), the smallest of all 11 sub-basins
- Deep-water portion (marine waters landscape class) comprises 4,416 acres (6.9 square miles), or 25% of the total sub-basin area.

Nearshore area

- Nearshore portion comprises 13,376 acres (20.9 square miles), or 75% of the total sub-basin area.
- Nearshore area within this sub-basin is 3% of the nearshore area of the entire Puget Sound basin.
- Contains 96 miles of shoreline (beaches landscape class).
- The "key" bays (landscape class) identified in this sub-basin is Liberty Bay, Fletcher Bay, Dyes Inlet, and Sinclair Inlet.
- Fifteen linear miles (16%) of the shoreline is designated as marine riparian (defined as the estimated area of length overhanging the intertidal zone).
- In this sub-basin, 16% of the shoreline (15 linear miles) has eelgrass (*Zostera marina* and *Z. japonica*); may be patchy or continuous.
- In this sub-basin, floating kelp does not occur. In this sub-basin, 18% of the shoreline (17 linear miles) has non-floating kelp; may be patchy or continuous.

Landscape Conditions

Landscape conditions for this sub-basin are depicted in Figures E-8.1 through 8.3 and E-9.4 of Appendix E.

Pocket Estuary Analysis

We identified 39 pocket estuaries in this sub-basin. This sub-basin contains the greatest concentration of pocket estuaries in Puget Sound (1.86 per square mile). Seventeen of the 39 pocket estuaries are located in the Dyes Inlet region, with the remaining pocket estuaries distributed across the landscape in a relatively even distribution.

- Freshwater sources were observed in greater than two-thirds of the pocket estuaries,
- Based on the assumptions listed in Appendix B, all three of the Chinook functions (feeding, osmoregulation and refuge) were estimated to occur in 24 of the 39 pocket estuaries. Most of the remaining pocket estuaries were estimated to have two of the three Chinook functions,
- Six pocket estuaries were estimated to be *properly functioning*. Seven pocket estuaries were estimated to be *not properly functioning*. The remaining pocket estuaries were recorded as *at risk*.

Drift Cell Analysis

The drift cell characterization developed for this sub-basin is presented in Appendix E, Figure E-8.5 (Main Basin) and subsequent text. Recommendations for protection and restoration are highlighted in Tables 6-18 and 6-19.

Threats/stressors

Loss and/or simplification of delta and delta wetlands

Natal estuaries for Chinook salmon do not occur in this sub-basin. No information is presented for smaller, non-natal deltas and delta wetlands.

Alteration of flows through major rivers

Larger-scale flow alterations are not present in this sub-basin. Smaller dams and diversions likely exist but are not identified here.

Modification of shorelines by armoring, overwater structures and loss of riparian vegetation/LWD

The projected population growth in Kitsap County between 2000-2025 is 43% (99, 602 people) (PSAT 2004). In this sub-basin, shoreline armoring occurs along 56 miles (59%) of the shoreline. Over 31 miles of shoreline are classified as 100% armored. Over 17 miles are classified as 0% armored. The total number of overwater structures is 2,383, consisting of ramps (98), piers and docks (256), small slips (1,936) and large slips (93). Overwater structures are observed in greater concentrations where armoring occurs. Within 300 feet of shore railroad grades occur along 2.6 miles, along a section of heavily armored shoreline in the southern portion of Sinclair Inlet.

Contamination of nearshore and marine resources

Regions with 15% or greater impervious surface are concentrated in Dyes Inlet and Sinclair Inlet, as well as Liberty Bay (PSAT 2004). Sediment samples analyzed from 1997-1999 reveal the majority of observed sediment contamination was located in urban waters such as Sinclair Inlet (PSWQAT 2002a). Over all years for which samples were collected and analyzed, Sinclair Inlet had higher levels of metals (copper, lead, mercury, silver, zinc) than any other location sampled in Puget Sound.

Figure E-8.3 illustrates the distribution of water quality impairments in this sub-basin.

Alteration of biological populations and communities

Stations sampled as part of the Ecology/NOAA 1997-1999 evaluation of sediment quality exhibited impaired invertebrate communities in Sinclair Inlet and Dyes Inlet (PSWQAT 2002a).

There are approximately 8 hatcheries releasing various species of salmonids into the Port Madison/Sinclair Inlet sub-basin, which may affect community structure at certain times of the year. Because of poor water quality, there are no commercial shellfish aquaculture operations in the sub-basin, however, there are several floating net pen aquaculture facilities. Overharvest of fisheries species in the past, continued recreational fishing pressure, loss of critical habitats and poor water quality have potentially greatly altered biological populations and communities within the sub-basin but comparative studies with other sub-basins in Puget Sound have not been conducted. Specific hatchery reform recommendations for this region have been formulated by the Hatchery Scientific Review Group available at the following websites.
http://www.lltk.org/pdf/HSRG_Recommendations_February_2002.pdf
http://www.lltk.org/pdf/HSRG_Recommendations_March_2003.pdf

Transformation of land cover and hydrologic function of small marine drainages via urbanization

Despite the small size of this sub-basin, we identified more pocket estuaries here than in the entire main basin of Puget Sound. Only 5 of the 39 pocket estuaries analyzed were determined to not be properly functioning for juvenile Chinook, largely due to urbanization impacts. Seven additional pocket estuaries are at risk of losing significant functions due to urbanization and many shoreline areas and watersheds are still rapidly urbanizing within the sub-basin. See Figure E-9.4 – list of pocket estuaries and noted stressors from visual observation via oblique aerial photos.

Transformation of habitat types and features via colonization by invasive plants

Spartina spp is not found in this sub-basin. 9% of the shoreline (9 miles) contains *Sargassum muticum*, which may be patchy or continuous.

B. Evaluation

In this section we list goals and evaluate the level of realized function for natal and non-natal Chinook, summer chum, and bull trout. From this we then list each of the proposed protection and restoration actions for this sub-basin, and describe the benefits to natal Chinook, non-natal Chinook, and summer chum and bull trout (if any).

Goals for listed salmon and bull trout whose natal streams are in this sub-basin

a) Though no independent populations of Chinook emanate from this sub-basin there are are Chinook documented in streams such as Gorst Creek. Provide early marine support to ensure that fish using these dispersed habitats contribute to population and ESU viability..

Goals for listed salmon and bull trout whose natal streams are outside this sub-basin

a) Provide support for all neighboring Puget Sound Chinook salmon populations.
b) Maintain and/or increase forage fish production as prey for non-natal salmon populations
c) Provide spatial structure and diversity support for populations of Chinook salmon from within the main basin (e.g., central Puget Sound sub-basin).

Realized function for listed salmon and bull trout

Fry migrant Chinook – Some of the fish emanating from streams such as Gorst Creek may adopt this life history strategy and rely on shallow, protected habitats in the vicinity of their natal estuaries. Two-thirds of the pocket estuaries in this sub-basin are estimated to be "at risk" by one or more landscape stressors, though the opportunity exists to derive some function (feeding and growth, refuge, and/or physiological transition) from many of the pocket estuaries in this sub-basin should fry migrants from this or other sub-basins (e.g., central sound) reach the shoreline habitats (Figure E-9.2). The density of pocket estuaries in this sub-basin may contribute little to the the viability of fry migrant Chinook in the Puget Sound ESU because the nearest independent populations are (1) fairly distant from this sub-basin's pocket estuary resources, and (2) not currently expressing significant fry migrant (or delta fry) trajectories

Delta fry Chinook – Natal estuaries for independent populations of Chinook salmon are not present in this sub-basin. Delta fry trajectories may occur in fish emanating from streams such as Gorst Creek, but these small natal estuaries probably to not provide much habitat capacity.

Parr migrant Chinook – On average this life history type is the most abundant in Puget Sound. Parr migrants and yearlings from neighboring sub-basins are most likely to utilize available nearshore habitats of this sub-basin because these fish are larger and capable of surviving greater swimming distances from the natal estuaries in central and south Puget Sound. Connectivity between habitat types and landscape classes is critical to ensure successful exploitation of available habitats. Parr migrants will encounter heavily armored shorelines, at risk or not properly functioning pocket estuaries, sewage outfalls and chemical contamination throughout much of Sinclair Inlet. Conditions are similar, but improved slightly in Dye Inlet with the exception of some areas with depressed dissolved oxygen levels. Parr migrants will encounter generally improved conditions moving north through Port Orchard with the exception of Liberty Bay where temperature, chemicals and low dissolved oxygen are evident (Figure E-9.3). Finally, the Port Madison herring stock is an important forage fish for parr migrants.

Yearling Chinook –Connectivity between habitat types and landscape classes is very important to yearlings from central sound populations, and other populations moving about broadly within Puget Sound. Yearling migrants will be exposed to the same types of stressors and ramifications as described in the parr migrant section above. Yearling migrants can derive functions (e.g., foraging, refuge, migratory pathway) from available nearshore habitats. Forage fish from the Port Madison herring stock will be especially important to this life history type as yearlings from multiple Chinook populations migrate throughout Puget Sound.

Sub-adult and adult Chinook – Larger fish migrating through this sub-basin may need to contend with issues such as toxic contaminants in the food chain and sediment contamination. Researchers from WDFW have documented that, in general, Chinook salmon living in or migrating through Puget Sound (specifically in central and south sound) are more contaminated with PCBs than stocks outside of Puget Sound (e.g., Columbia River, WA coast). See Figure 4.7 in Section 4. Residence time in the central and southern Puget Sound basins is suspected as a "primary predictor of PCB concentration in Chinook salmon" and as such, those salmon spending the greatest amount of time in central and south sound exhibit the greatest PCB concentrations (WDFW, unpublished data) (Figure 4-8). Another toxic contaminant of concern in Puget Sound is PBDEs, a common chemical that, like PCBs, are found in greater concentrations in resident Chinook salmon versus migratory Chinook salmon.

Listed summer chum – We hypothesize that Hood Canal/Eastern Strait of Juan de Fuca summer chum salmon do not use this sub-basin.

Anadromous bull trout – We hypothesize that anadromous bull trout do not use this sub-basin.

Table 6-18. Recommended protection actions for Port Madison/Sinclair Inlet

Protection action	**Benefit to Natal Chinook**	**Benefit to Other (non-natal) Chinook**	**Benefit to summer chum, bull trout, other fish**
Aggressively protect all pocket estuaries regardless of their current function or proximity to natal deltas within the central Puget Sound sub-basin. (See Fig. E-9.4)	Support for weakly swimming migrants from systems such as Gorst Creek	Sustained feeding, growth, refuge and migration functions for all Puget Sound populations, especially from main Basin and Hood Canal	Sustained feeding, growth, refuge and migration functions other species
Protect water quality from further degradation	Support for small, sensitive fish from systems such as Gorst Creek	Sustained migration and reduced mortality for PS populations	Sustained migration and reduced mortality for other species
Protect against catastrophic events		Sustained migration and reduced mortality for PS populations	Sustained migration and reduced mortality for other species
Protect Port Madison (and the smaller Dyes Inlet) herring stock, as well as forage fish spawning grounds		Sustained feeding and growth for PS populations	Sustained feeding and growth for other species

Table 6-19. Recommended improvement actions for Port Madison/Sinclair Inlet

Improvement action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Consider wastewater reclamation and reuse for all current and planned new sewage discharges throughout the sub-basin	Improved support for small, sensitive fish from systems such as Gorst Creek	Improved migration and reduced mortality for PS populations	Improved migration and reduced mortality for other species
Add enhanced treatment for stormwater discharging directly to Puget Sound to the same standards as for salmon bearing streams	Improved support for small, sensitive fish from systems such as Gorst Creek	Improved migration and reduced mortality for PS populations	Improved migration and reduced mortality for other species
Encourage voluntary re-vegetation of cleared residential shorelines throughout the sub-basin. Put special emphasis on maintaining connectivity, primary production and water quality		Improved feeding, growth, refuge and migration functions for all Puget Sound populations, especially from main Basin and Hood Canal	Improved feeding, growth, refuge and migration functions other species
Restore drift cell function in Shoreline Restoration Target Area 9 (Main Basin Map Fig. E-8.5)		Improved feeding, growth, refuge and migration functions for all Puget Sound populations, especially from main Basin and Hood Canal	Improved feeding, growth, refuge and migration functions other species
Restore areas containing contaminated sediment hot spots and ongoing toxic discharges.		Improved migration and reduced mortality for PS populations	Improved migration and reduced mortality for other species
Reform hatchery practices		Improved feeding and growth	Improved feeding and growth of other species

6.10 Carr/Nisqually

1. Salmon Use

Chinook

The TRT has identified one independent population emanating from this sub-basin:

- Nisqually

a) Juvenile

- Juvenile Chinook salmon of all four life history types from the Nisqually natal population utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor (juvenile salmon functions).
- This sub-basin provides direct support to meeting the Chinook ESU criteria by supporting rearing of juveniles of many populations from almost all geographic regions of origin.
- Populations from south Puget Sound, particularly fish from the central Puget Sound sub-basin where most delta functions have been lost, also utilize this sub-basin for feeding and growth, refuge, physiological transition and as a migratory corridor.

b) Adult

- Adult Chinook salmon from the Nisqually natal population derive functions (i.e., feeding, migratory corridor) from this sub-basin. See Figure E-10.1 for map of other Chinook use besides the Nisqually River.
- Adult Chinook salmon from non-natal populations also utilize this sub-basin
- This sub-basin provides direct support to meeting the Chinook ESU criteria by supporting rearing of sub adults and adults of many populations from almost all geographic regions of origin.

Other Listed Species (not comprehensively reviewed or assessed for this sub-basin)

- Chum salmon: None of the eight populations of the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU targeted for recovery emanate from this sub-basin. However, summer chum populations within the ESU are documented to exist in this sub-basin in Chambers Creek and Burley Creek.
- Bull trout (anadromous): Preliminary core populations within the Puget Sound Management Unit of bull trout do not emanate from this sub-basin. However, the upper and lower Nisqually River is considered important foraging, migration, and overwintering habitat for recovering populations from the north (USFWS 2004).

2. Ecological and Landscape Conditions

Food Web, Ecological Conditions

Portions of this sub-basin exhibit poor water quality, and if not addressed or corrected, may continue to negatively affect the ecology of this sub-basin. As in the Central Puget Sound sub-basin, toxic contaminants such as PCBs and PBDEs (and others) are polluting the food web of Puget Sound, particularly the central and south sound basins (three sub-basins: central Puget Sound, Carr-Nisqually, south Puget Sound). Natal Chinook salmon populations from the two basins as well as a primary salmon prey (i.e., Pacific herring) appear to be contaminated with toxics (see following sections for more detail). These “resident” salmon (i.e., natal populations) exhibit greater concentrations of toxics when compared to migratory salmon (i.e., non-natal populations) passing through each sub-basin.

A comprehensive approach toward restoration of the historical water quantity, nutrients, and water quality baseline pathways and patterns will likely be necessary to protect and restore ecological functions to conditions supporting viable populations in protected sub-basins with limited circulation, such as this sub-basin. Preventing further degradation of D.O. and other water quality factors including avoidance of further stormwater loadings and NPDES discharge loadings will be key. Beyond that, redirection of sewage treatment discharges to upland treatment and reuse/recharge systems will be needed to reduce summer time loadings that are degrading D.O. levels and shifting nearshore community structure (Bill Graeber, NOAA-TRT, pers. comm.).

Re-creation of the Nisqually Delta estuary represents a riverine estuary restoration potential of regional significance. Restoring the Nisqually Delta estuary represents one of only a few opportunities to recover an increment of the 70% historic loss of this habitat type in a block large enough to be a fully functional river estuary and to restore ecologic processes at the regional scale. Watershed efforts already underway on restoration of the estuary should be fully supported and further encouraged (Bill Graeber, NOAA-TRT, pers. comm.)

Landscape Conditions

The Carr-Nisqually sub-basin lies inland of a significant underwater geologic sill and tidal constriction through the Tacoma Narrows. This effects the sub-basin and neighboring South Sound sub-basin in several ways. Extreme tidal ranges can be up to 18 feet, nearly twice as large as the Strait of Juan de Fuca and San Juan Islands because of tidal pumping through the Narrows. The sill also isolates the waters of Carr-Nisqually and South Sound sub-basins so that the oceanographic residence time is considerably longer than the main basin leading to a susceptibility for nutrient pollutants to concentrate over time leading to eutrophication.

Overall area

- Total area (deep-water plus nearshore) is 51,136 acres (79.9 square miles)
- Deep-water portion (marine waters landscape class) comprises 34,688 acres (54.2 square miles), or 68% of the total sub-basin area.

Nearshore area

- Nearshore portion comprises 16,448 acres (25.7 square miles), or 32% of the total sub-basin area. As part of the nearshore, the Nisqually estuary is a natal estuary (landscape class) for the independent Chinook population listed above, comprising 4.15 square miles (16%) of the total nearshore area within this sub-basin.
- Nearshore area within this sub-basin is 4% of the nearshore area of the entire Puget Sound basin.
- Contains 156 miles of shoreline (beaches landscape class).
- The “key” bays (landscape class) identified in this sub-basin are Chambers Bay, Taylor Bay, Oro Bay, Amsterdam Bay, Filuce Bay, Henderson Bay, Wallochet Bay, and Horsehead Bay.
- Forty-four linear miles (28%) of the shoreline is designated as marine riparian (defined as the estimated area of length overhanging the intertidal zone).
- In this sub-basin, 34% of the shoreline (53 linear miles) has eelgrass (*Zostera marina* and *Z. japonica*); may be patchy or continuous.
- In this sub-basin, 4% of the shoreline (7 linear miles) has floating kelp; may be patchy or continuous. Also in this sub-basin, 4% of the shoreline (6 linear miles) has non-floating kelp; may be patchy or continuous.

Figures E-10.1 through E-10.5 in Appendix E provide additional information about landscape conditions in this sub-basin.

Pocket Estuary Analysis

We identified 35 pocket estuaries in this sub-basin. This sub-basin contains a high concentration of pocket estuaries in Puget Sound (1.35 per square mile). The many pocket estuaries are distributed relatively uniformly throughout the sub-basin.

- Freshwater sources were observed in fewer than half (15) of the pocket estuaries,
- Based on the assumptions listed in Appendix B, all three of the Chinook functions (feeding, osmoregulation and refuge) were estimated were estimated to occur in 13 of the 35 pocket estuaries. Most of the remaining pocket estuaries were estimated to have two of the three Chinook functions,
- Nineteen pocket estuaries were estimated to be *properly functioning*. Five pocket estuaries were estimated to be *not properly functioning*. The remaining 11 pocket estuaries were recorded as *at risk*.

Drift Cell Analysis

The drift cell characterization developed for this sub-basin is presented in Appendix E, Figure E-10.5 and subsequent text. Recommendations for protection and restoration are highlighted in Tables 6-20 and 6-21.

Threats/stressors

Loss and/or simplification of delta and delta wetlands

Comparison of historical wetland area and wetland area reported in Bortleson et al. (1980) revealed that for the Nisqually delta, the estimated area of subaerial wetlands decreased from historical to date of survey in 1980 from 2.20 to 1.58 square miles (decreased by 0.62 square miles). The estimated area of intertidal wetlands decreased from historical to date of survey in 1980 from 2.85 to 2.24 square miles (decreased by 0.61 square miles). The loss of lowland wetlands has not been as pronounced as in other larger estuaries to the north, and is much less developed than other large, natal estuaries. Diking for agriculture purposes is the primary reason for any loss, but in recent years some dikes have been breached (or removed) to allow for increased tidal inundation and exchange. This is expected to greatly benefit salmon and bull trout.

Alteration of flows through major rivers

Two dams occur on the Nisqually River, Alder dam and LaGrande dam. A natural barrier on the river is thought to have occurred in the location of LaGrande dam (USFWS 2004). Other large-scale flow alterations are not present in this sub-basin. Smaller dams and diversions likely exist but are not identified here. Diking is present in the lower river and estuary.

Modification of shorelines by armoring, overwater structures and loss of riparian vegetation/LWD

The projected population growth in Pierce and Thurston counties between 2000-2025 is 34% (241,337 people) and 62% (129,470 people), respectively (PSAT 2004). In this sub-basin, shoreline armoring occurs along nearly 68 miles (44%) of the shoreline. Thirty-three miles of shoreline are classified as 100% armored. Over 53 miles are classified as 0% armored. The total number of overwater structures is 1,588, consisting of ramps (177), piers and docks (346), small slips (1,058) and large slips (7). Overwater structures generally overlap with the shoreline armoring regions mentioned above, especially Hale Passage, Henderson Bay and portions of Carr Inlet. Within 300 feet of shore railroad grades occur along 16.7 miles, following the entire shoreline from the eastern edge of the Nisqually delta, north to the Tacoma Narrows bridge and beyond.

The Lowland Nisqually River exhibits a branching and multiple channel pattern and over the last 130 years, frequent channel shifts have occurred (Collins et al, 2003). Large wood jams are a critical component to maintaining the anastomosing character of the lower Nisqually River. Patches of mature forests on the floodplain of the Nisqually River still exist and contributed to the "channel-switching dynamic" of this system (Collins et al, 2003). Field data collected in 1998 showed the Nisqually River contained approximately 8 times more wood per channel width than the Snohomish and 21 times more wood than the Stillaguamish, most of the difference "accounted for by the abundance of wood in jams in the Nisqually River" (Collins et al, 2003).

Contamination of nearshore and marine resources

Regions with 15% or greater impervious surface are found mostly along the eastern shore from Steilacoom, north (PSAT 2004).

In this sub-basin, toxic contaminants such as PCBs in the food chain are a concern, from both past and present activities. Sediment contaminant levels were compared from 1989-1996 to levels in 2000, and revealed that the most numerous increases in PAH levels occurred on East Anderson Island, compared to other sample locations (PSWQAT 2002a).

See Figure E-10.3 for information about the distribution of water quality impairments in this sub-basin.

Alteration of biological populations and communities

Pacific herring have been found to be "3 to 11 times more contaminated with PCBs in central and south Puget Sound than the Strait of Georgia" (WDFW, unpublished data). These WDFW results from 2004 are similar to those reported in 1999 and 2000 in PSWQAT (2002a), where body burdens of PCBs were higher in Pacific herring from the central basin (Port Orchard) and southern Puget Sound basin (Squaxin Pass) than Pacific herring from northern Puget Sound and the Strait of Georgia. Finally, the WDFW researchers report that the PCB-contaminated food web of Puget Sound may explain the source of the PCBs identified in southern resident killer whales. See the ecological section, above, for additional information.

There are approximately 13 hatcheries releasing various salmonids into this sub-basin, which may cause alteration of community structure, competition for available prey resources and predation of wild fish. There are several commercial shellfish aquaculture operations, mostly raising Pacific (Japanese) oyster, Manilla clams and various native species. Significant recreational fishing pressure may have changed the historic community structure of fish species throughout this sub-basin. Specific hatchery reform recommendations for this region have been formulated by the Hatchery Scientific Review Group available at the following websites.
http://www.lltk.org/pdf/HSRG_Recommendations_February_2002.pdf
http://www.lltk.org/pdf/HSRG_Recommendations_March_2003.pdf

Transformation of land cover and hydrologic function of small marine discharges via urbanization

We identified and analyzed 35 pocket estuaries for their level of function for juvenile Chinook. Urbanization is currently stressing 8 of those pocket estuaries. Days Island and Burley lagoon were determined to be not properly functioning for juvenile Chinook. See Figure E-10.4 for a list of pocket estuaries and an indication of the stressors noted through review of oblique aerial photos.

Transformation of habitat types and features via colonization by invasive plants

Spartina spp are not found in this sub-basin. 15% of the shoreline (24 miles) contains *Sargassum muticum*, which may be patchy or continuous.

B. Evaluation

In this section we list goals and evaluate the level of realized function for natal and non-natal Chinook, summer chum, and bull trout. From this we then list each of the proposed protection and restoration actions for this sub-basin, and describe the benefits to natal Chinook, non-natal Chinook, and summer chum and bull trout (if any).

Goals for listed salmon and bull trout whose natal streams are in this sub-basin

a) Provide early marine support for all four life history types of the Nisqually population emanating from this sub-basin,
b) Provide support for sub-adult and adult Chinook salmon populations who utilize habitats within this sub-basin as a migratory corridor and grazing area,
c) Provide marine support for sub-adult and adult anadromous bull trout populations using the lower Nisqually as foraging, migration, and overwintering habitat,
d) Provide marine support for summer chum populations outside of the eight populations targeted for recovery (e.g., Hood Canal/Eastern Strait of Juan de Fuca)
e) Provide for connectivity of habitats; also, adequate prey resources, marine foraging areas, and migratory corridors for juvenile, sub-adult and adult Chinook, summer chum, and bull trout

Goals for listed salmon and bull trout whose natal streams are outside this sub-basin

a) Provide continued support for all neighboring Puget Sound populations, specifically significant non-natal Chinook salmon use of this sub-basin by fish primarily from the main basin (juveniles, sub-adults, and adults).

Realized function for listed salmon and bull trout

Fry migrant Chinook – Over two-thirds of the pocket estuaries within five miles of the Nisqually delta are estimated to be properly functioning (Figure E-10.2) and with minimal stressors noted (Figure E-10.4). Slightly over half the pocket estuaries between five and ten miles from the Nisqually delta are estimated to be properly functioning. Fry migrants emerging from the delta in search of the shallow water, low-velocity habitats associated with pocket estuaries will find fully functioning pocket estuaries nested within somewhat protected shorelines from the western edge of the delta, stretching toward Johnson Point, as well as across Nisqually Reach to include the southern half of Anderson Island. Pocket estuaries are nearly absent along the eastern shore as fry migrants emigrate northward. This region of shoreline exhibits armored shorelines with a continuous railroad grade along the shoreline, but with a relatively unpopulated shoreline region up to Steilacoom. Connectivity between habitat types and landscape classes, including intact freshwater "lenses" (or bands) along shorelines, is essential for small-sized fry migrants emerging from the Nisqually delta in search of rearing, refuge and osmoregulatory habitats within pocket estuaries. Any disruption such as habitat fragmentation or reduction/elimination of freshwater contribution in areas between the delta and destination pocket estuaries would be detrimental to this life history type.

Delta fry Chinook – The net loss of intertidal wetlands within the Nisqually delta from historic conditions was relatively low (0.61 mile^2 or 395 acres) (Bortleson et al., 1980). Consequently, the opportunity for delta fry to access delta habitat is presently realized, and this is improving each year (e.g., up to 1000 acres are slated for recovery by 2006). On average, delta fry are an abundant Chinook salmon life history type in Puget Sound, entering the estuarine environment at a small size, and utilizing the myriad estuarine habitats for rearing, osmoregulatory function and predator avoidance (refuge) until reaching a size (i.e., parr migrant or larger) where they venture out to the neritic and pelagic waters of Puget Sound. As with fry migrants, connectivity between habitat types and landscape classes is essential. Delta fry moving out of the delta environment (as larger fish) can access mostly protected shorelines and properly functioning pocket estuaries to the north and northwest of the Nisqually delta. As delta fry make their way to the northern reaches of this sub-basin, the fish are exposed to several wastewater discharges and chemicals. In addition, "resident" fish from this and other sub-basins (central Puget Sound and south Puget Sound) are experiencing higher toxic contaminant body burden levels versus those salmon migrating through these sub-basins from elsewhere (WDFW, unpublished data).

Parr migrant Chinook – Many of the Puget Sound Chinook salmon migrate to the ocean as sub-yearlings (Myers et. al., 1998), and on average this life history type is the most abundant in Puget Sound. Parr migrants from the Nisqually Chinook salmon population, as well as populations from central Puget Sound, have access to pocket estuaries occurring at a rate of 1.35 per square mile throughout the sub-basin (>50% are estimated as properly functioning). Parr migrants from the Nisqually population spend anywhere from a week to a month or more in the estuary before moving out into the larger waters of the sub-basin, and beyond. Connectivity between habitat types and landscape classes is essential to this life history type. Parr migrants moving south out of the central Puget Sound sub-basin are thought to greatly utilize, and depend on the shoreline habitats within the Carr-Nisqually sub-basin. The shorelines of McNeil Island, Anderson Island and the terminus of Henderson Bay exhibit pocket estuaries either properly functioning or at risk, as well as relatively unarmored shorelines.

Yearling – Any reduction in capacity as a result of non-support of the other life history types (i.e., primarily parr migrants) within this sub-basin will negatively affect yearling migrants. Connectivity between habitat types and landscape classes is very important to yearlings from the Nisqually population, and other populations moving about broadly within Puget Sound. Yearling migrants will be exposed to the same types of stressors and ramifications as described in the other sections above. Yearling migrants can derive functions (e.g., foraging, refuge, migratory pathway) from available nearshore habitats as described above. Of concern are the toxic contaminants polluting the food web in the three southern sub-basins, and the body burden effects on salmon.

Sub-adult and adult Chinook - Larger fish migrating through this sub-basin must contend with water quality issues and toxic contaminants in the food chain. Researchers from WDFW have documented that, in general, Chinook salmon living in or migrating through Puget Sound (specifically in central and south sound) are more contaminated with PCBs than stocks outside of Puget Sound (e.g., Columbia River, WA coast). See Figure 4.7 in Section 4. Residence time in the central and southern Puget Sound basins is suspected as a "primary predictor of PCB concentration in Chinook salmon" and as such, those salmon spending the greatest amount of time in central and south sound exhibit the greatest PCB concentrations (WDFW, unpublished data) (Figure 4-8). Another toxic contaminant of concern in Puget Sound is PBDEs, a common chemical that, like PCBs, are found in greater concentrations in resident Chinook salmon versus migratory Chinook salmon.

Listed summer chum – We hypothesize that none of the eight populations of the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU targeted for recovery use this sub-basin. However, those populations of summer chum listed in the Salmon Use section, above, do utilize this sub-basin.

Anadromous bull trout – Bull trout have not been observed in the Nisqually River in recent years and it is not known if a remnant population persists (USFWS 2004). However, it is believed that as populations recover, the lower Nisqually River and the McAllister Creek estuary will be important to bull trout in this region of Puget Sound (specifically proximate populations to the north), as foraging, migration, and overwintering habitat (USFWS 2004).

Table 6-20. Recommended protection actions for Carr/Nisqually

Protection action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Aggressive protect areas, especially shallow water/low gradient habitats and pocket estuaries, within 5 miles of the Nisqually delta	Sustained feeding, growth, refuge, osmoregulation and migratory functions for Nisqually population	Sustained feeding, growth, refuge and migratory functions for other populations, especially Main Basin populations	Sustained feeding, growth, refuge and migratory functions for other species
Protect against catastrophic events, especially any spills in the Narrows as this is a bottleneck region for migration.	Sustained growth and migratory functions	Sustained growth and migratory functions	Sustained growth and migratory functions for other species
Protect small tributary regions throughout the sub-basin	Sustained feeding, growth, refuge, osmoregulation and migratory functions for Nisqually population	Sustained feeding, growth, refuge and migratory functions for other populations, especially Main Basin populations	Sustained feeding, growth, refuge and migratory functions for other species
Protect functioning drift cells supporting eelgrass bands and depositional features along Anderson, McNeil, Ketron and Fox island shorelines and the Gig Harbor peninsula shoreline along the Narrows (Shoreline Protection Target Areas 3,4,8 and 9 in Figure E-10.5). Consider designating these shorelines for the highest level of protection within shoreline master programs and critical areas ordinances and pass strong policies limiting increased armoring of these shorelines and support landowner incentive programs for conservation.	Sustained feeding, growth, refuge and migratory functions	Sustained feeding, growth, refuge and migratory functions	Sustained feeding, growth, refuge and migratory functions for other species

Table 6-21. Recommended improvement actions for Carr/Nisqually

Improvement action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Add enhanced treatment for stormwater discharging directly to Puget Sound to the same standards as for salmon bearing streams.	Improved feeding, growth, osmoregulation and refuge, reduced mortality	Improved feeding and refuge	Improved feeding and refuge for other species
Consider wastewater reclamation and reuse retrofits for McNeil Island and Solo Point discharges.	Improved feeding, growth, osmoregulation and migratory functions, reduced mortality	Improved feeding and migratory functions	Improved feeding and migratory functions for other species
Aggressively promote shellfish environmental codes of practice.	Improved feeding, refuge and migratory functions	Improved feeding, refuge and migratory functions	Improved feeding, refuge and migratory functions
Aggressive restore areas, especially shallow water/low gradient habitats and pocket estuaries, within 5 miles of the Nisqually delta	Improved feeding, growth, refuge, osmoregulation and migratory functions for Nisqually population	Improved feeding, growth, refuge and migratory functions for other populations, especially Main Basin populations	Improved feeding, growth, refuge and migratory functions for other species
Continue to restore the Nisqually delta - up to 1000 acres should be restored within the next couple years	Improved feeding, growth, refuge, osmoregulation and migratory functions for Nisqually population	Improved feeding, growth, refuge and migratory functions for other populations, especially Main Basin populations	Improved feeding, growth, refuge and migratory functions for other species
Retrofit the railroad grade from the Nisqually River to Point Defiance to address access to blocked pocket estuaries. Remove the separation of upland and aquatic environments	Improved feeding, growth, refuge, osmoregulation and migratory functions for Nisqually population	Improved feeding, growth, refuge and migratory functions for other populations, especially Main Basin populations	Improved feeding, growth, refuge and migratory functions for other species
Increase the tidal prism of the Nisqually delta through dike removal and elevation of Interstate 5 across the freshwater tidal portions of the delta.	Improved feeding, growth, refuge, osmoregulation and migratory functions for Nisqually population	Improved feeding, growth, refuge and migratory functions for other populations, especially Main Basin populations	Improved feeding, growth, refuge and migratory functions for other species
Conduct limited beach nourishment on a periodic basis to mimic the natural sediment transport processes in select sections where corridor functions may be impaired (Shoreline Restoration Target Areas 1, 2,5, 6 and 7 in Fig. E-10.5).	Improved feeding, growth, refuge and migratory functions	Improved feeding, growth, refuge and migratory functions	Improved feeding, growth, refuge and migratory functions for other species
Encourage voluntary re-vegetation of cleared residential shorelines throughout the sub-basin.	Improved feeding, growth, refuge and migratory functions	Improved feeding, growth, refuge and migratory functions	Improved feeding, growth, refuge and migratory functions for other species

6.11 South Sound

A. Assessment

1. Salmon Use

Chinook

The TRT has identified no independent populations emanating from this sub-basin.

a) Juvenile

- Juvenile Chinook salmon from non-natal populations, primarily fish from central Puget Sound and the Carr-Nisqually sub-basins, utilize the shorelines and pocket estuaries for feeding and growth, refuge, physiological transition and as a migratory corridor (juvenile salmon functions). See Figure 3-1 for a list of all Chinook populations. This sub-basin provides direct support to meeting the Chinook ESU criteria by supporting rearing of juveniles of many populations from all five geographic regions of origin, but is likely most importantly for populations from the geographic region it lies within, and adjacent geographic regions of origin.

b) Adult

- Sub-adult and adult salmon from neighboring populations utilize habitats within this sub-basin as a passage corridor and grazing area. This sub-basin provides direct support to meeting the Chinook ESU criteria by supporting rearing of sub adults of many populations from all five geographic regions of origin, but is likely most importantly for populations from the geographic region it lies within, and adjacent geographic regions of origin.

Other Listed Species (not comprehensively reviewed or assessed for this sub-basin)

- Chum salmon: None of the eight populations of the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU targeted for recovery emanate from or use this sub-basin. However, summer chum populations within the ESU are documented to exist in this sub-basin in Coulter Creek, Sherwood Creek, Deer Creek, Cranberry Creek, Johns Creek, and Rocky Creek.
- Bull trout (anadromous): Preliminary core populations within the Puget Sound Management Unit of bull trout do not exist in this sub-basin. It is not known if any anadromous bull trout use this sub-basin.

2. Ecological and Landscape Conditions

<u>Food Web, Ecological Conditions</u>

Portions of this sub-basin exhibit poor water quality, and if not addressed or corrected, may continue to negatively affect the ecology of this sub-basin. As in the Central Puget Sound and Carr-Nisqually sub-basin, toxic contaminants such as PCBs and PBDEs (and others) are polluting the food web of Puget Sound, particularly the central and south sound basins (three sub-basins: central Puget Sound, Carr-Nisqually, south Puget Sound). Natal Chinook salmon populations from the two basins as well as a primary salmon prey (i.e., Pacific herring) appear to be contaminated with toxics (see following sections for more detail). These "resident" salmon (i.e., natal populations) exhibit greater concentrations of toxics when compared to migratory salmon (i.e., non-natal populations) passing through each sub-basin.

The Department of Natural Resources hypothesizes that because of the extreme tidal range of South Sound and the exacting physiological requirements of eelgrass, the species is effectively precluded from growing in this sub-basin naturally. At extreme low tides, eelgrass would be subject to dessication. At extreme high tides, light would not penetrate the water to a sufficient intensity to sustain eelgrass growth. (Tom Mumford, WADNR, personal communication) This hypothesis should receive further testing. What South Sound does have in abundance is mudflats. These habitats can exhibit extreme primary productivity through production of a diatom biofilm that grows on the mudflat surface. This bio-film is receiving considerable attention for its role in overall primary productivity in intertidal systems as well as its role in stabilizing fine sediments.

A comprehensive approach toward restoration of the historical water quantity, nutrients, and water quality baseline pathways and patterns will likely be necessary to protect and restore ecological functions to conditions supporting viable populations in protected sub-basins with limited circulation, such as the Carr-Nisqually, Hood Canal, Padilla sub-basins. Preventing further degradation of D.O. and other water quality factors including avoidance of further stormwater loadings and NPDES discharge loadings will be key. Beyond that, redirection of sewage treatment discharges to upland treatment and reuse/recharge systems will be needed to reduce summer time loadings that are degrading D.O. levels and shifting nearshore community structure. In South Sound the approach may need to address retrofitting of the existing sewage treatment facilities (e.g., LOTT, Shelton, etc.) and alternative approaches to future projects to reduce nutrient and contaminants loadings to the nearshore to improve D.O. and ecological functions supporting salmon. The same applies to existing and future stormwater treatment approaches (Bill Graeber, NOAA-TRT, pers. comm.).

Re-creation of the Deschutes River estuary represents a riverine estuary restoration potential of regional significance. Restoring the Deschutes River estuary represents one of only a few opportunities to recover an increment of the 70% historic loss of this habitat type in a block large enough to be a fully functional river estuary and to restore ecologic processes at the regional scale. In particular, based upon recent studies on pocket estuary utilization it appears the Deschutes River could serve a significant role in increasing the estuarine rearing potential for the Nisqually Chinook population which would serve to fill some of the ESU need for the life history diversity, spatial structure, productivity, and abundance that riverine estuaries can support (Bill Graeber, NOAA-TRT, pers. comm.)

Landscape Conditions

See Figures E-10.1 through 10.3, E11.4 and E-11.5 for a presentation of some of the landscape conditions for this sub-basin

Overall area

- Total area (deep-water plus nearshore) is 57,344 acres (89.6 square miles), the smallest of all 11 sub-basins
- Deep-water portion (marine waters landscape class) comprises 22,848 acres (35.7 square miles), or 40% of the total sub-basin area.

Nearshore area

- Nearshore portion comprises 34,496 acres (53.9 square miles), or 60% of the total sub-basin area.
- Nearshore area within this sub-basin is 8% of the nearshore area of the entire Puget Sound basin.
- Contains 293 miles of shoreline (beaches landscape class).
- The "key" bays (landscape class) identified in this sub-basin is Henderson Inlet, Budd Inlet, Eld Inlet, Totten Inlet, Oakland Bay, North Bay, Rocky Bay, and Vaughn Bay.
- Ninety linear miles (31%) of the shoreline is designated as marine riparian (defined as the estimated area of length overhanging the intertidal zone).
- In this sub-basin, 3% of the shoreline (10 linear miles) has eelgrass (*Zostera marina* and *Z. japonica*); may be patchy or continuous.
- In this sub-basin, floating kelp does not occur. In this sub-basin, 32% of the shoreline (93 linear miles) has non-floating kelp; may be patchy or continuous.

Pocket Estuary Analysis

We identified 62 pocket estuaries in this sub-basin. They are distributed relatively uniformly throughout the sub-basin, with the exception of only a couple in Hammersley Inlet and Oakland Bay, none in southern Budd Inlet, and none in Pickering Passage.

- Freshwater sources were observed in less than half of the pocket estuaries,
- Based on the assumptions listed in Appendix B, all three of the Chinook functions (feeding, osmoregulation and refuge) were estimated were estimated to occur in 20 of the 62 pocket estuaries. Most of the remaining pocket estuaries were estimated to have two of the three Chinook functions,
- Twenty-six pocket estuaries were estimated to be *properly functioning*. Thirteen pocket estuaries were estimated to be *not properly functioning*. The remaining pocket estuaries were recorded as *at risk*.

Drift Cell Analysis

A drift cell characterization for this sub-basin assessed the role of longshore sediment transport processes in controlling the structure of certain features along the shoreline that support salmon. For example, the broad intertidal and subtidal shelves that provide shallow, vegetated patches and corridors along the shoreline are a depositional feature of soft sediments generally at the depositional portions of drift cells or at the intersection of longshore drift and deltaic processes.

The methods of this analysis are presented in Appendix E, Figure E-11.5 and subsequent text. Recommendations for protection and restoration are highlighted in Tables 6-22 and 6-23.

Threats/stressors

Loss and/or simplification of delta and delta wetlands

Natal estuaries for Chinook salmon do not occur in this sub-basin. There are many other smaller estuaries and delta wetlands in this sub-basin, but no information are presented here.

Alteration of flows through major rivers

Large-scale flow alterations are present on the Deschutes River at Capitol Lake. Refer to the Ecological Section above for information. Smaller dams and diversions likely exist but are not identified here.

Modification of shorelines by armoring, overwater structures and loss of riparian vegetation/LWD

The projected population growth in Thurston and Mason counties between 2000-2025 is 62% (129,470 people) and 52% (25,683 people), respectively (PSAT 2004). In this sub-basin, shoreline armoring occurs along 109 miles (37%) of the shoreline. Over 55 miles of shoreline are classified as 100% armored. Over 147 miles are classified as 0% armored. The total number of overwater structures is 2,626, consisting of ramps (83), piers and docks (228), small slips (2,308) and large slips (7). Overwater structure such as ramps, piers and docks generally overlap with the shoreline armoring regions mentioned above, especially Budd Inlet, Eld Inlet, northern Case Inlet and North Bay and portions of Pickering Passage. Within 300 feet of shore railroad grades occur along 9.1 miles, near the western terminus of Oakland Bay in Shelton.

Contamination of nearshore and marine resources

Regions with 15% or greater impervious surface are concentrated in Olympia and Shelton (PSAT 2004). Sediment samples analyzed from 1997-1999 reveal that some of the greatest toxicity was found in the Port of Olympia based on a series of four toxicity tests designed to gauge impacts on biota (PSWQAT 2002a). In addition, the South Puget Sound region was one of four regions with the greatest degree of degraded sediments (PSWQAT 2002a). 8.2% of the area of South Sound exceeds the state's sediment quality standard and 5.5% of the area exceeds the cleanup screening levels.

Water quality concerns are discussed elsewhere in this evaluation. Ten sewage outfalls and an unknown number of stormwater discharge are also observed in this sub-basin.

Numerous past and present activities contribute to the contamination of nearshore and marine resources in this sub-basin and include, but are not limited to, wastewater discharges from industrial and municipal sources; stormwater discharges; and other hazardous substance spills. These are discussed in more detail in Section 4. In this sub-basin, toxic contaminants such as

PCBs in the food chain are a concern. This is discussed in more detail in the realized function section, below.

Alteration of biological populations and communities

Pacific herring have been found to be "3 to 11 times more contaminated with PCBs in central and south Puget Sound than the Strait of Georgia" (WDFW, unpublished data). These WDFW results from 2004 are similar to those reported in 1999 and 2000 in PSWQAT (2002a), where body burdens of PCBs were higher in Pacific herring from the central basin (Port Orchard) and southern Puget Sound basin (Squaxin Pass) than Pacific herring from northern Puget Sound and the Strait of Georgia. Finally, the WDFW researchers report that the PCB-contaminated food web of Puget Sound may explain the source of the PCBs identified in southern resident killer whales. See the ecological section, above, for additional information.

There are approximately 6 hatcheries releasing various salmonids into this sub-basin, which may cause alteration of community structure, competition for available prey resources and predation of wild fish. In addition, the Squaxim Island Tribe maintains net pens for rearing coho salmon in Percival Cove, a part of the Budd Inlet/Deschutes estuary system. There are extensive commercial and recreational shellfish aquaculture operations, mostly raising Pacific (Japanese) oyster, Manilla clams and various native species, especially in Henderson Inlet, Eld Inlet, Totten Inlet, Oakland Bay and Hammersly Inlet systems. Significant recreational fishing pressure may have changed the historic community structure of fish species throughout this sub-basin. Specific hatchery reform recommendations for this region have been formulated by the Hatchery Scientific Review Group available at the following websites.
http://www.lltk.org/pdf/HSRG_Recommendations_February_2002.pdf
http://www.lltk.org/pdf/HSRG_Recommendations_March_2003.pdf

Transformation of land cover and hydrologic function of small marine drainages via urbanization

South Sound has more pocket estuaries than any other sub-basin in Puget Sound based on our analysis and only 8 are stressed with urbanization at this time. See Figure E-11.4 for a list of pocket estuaries and noted stressors from visual observation via oblique aerial photos.

Transformation of habitat types and features via colonization by invasive plants

Spartina spp is not found in this sub-basin. Also, 17% of the shoreline (50 miles) contains *Sargassum muticum*, which may be patchy or continuous.

B. Evaluation

In this section we list goals and evaluate the level of realized function for natal and non-natal Chinook, summer chum, and bull trout. From this we then list each of the proposed protection and restoration actions for this sub-basin, and describe the benefits to natal Chinook, non-natal Chinook, and summer chum and bull trout (if any).

Goals for listed salmon and bull trout whose natal streams are in this sub-basin

a) Although none of the 22 indpendent populations emanate from this sub-basin, Chinook use of South Sound streams has been documented and this use should be maintainted by support for nearshore functions in this sub-basin.

Goals for listed salmon and bull trout how natal streams are outside this sub-basin

a) Provide support for all neighboring Puget Sound Chinook salmon populations from the main basin (e.g., Chinook salmon from the central Puget Sound and Carr-Nisqually sub-basins).
b) Provide support for sub-adult and adult Chinook salmon populations who utilize habitats within this sub-basin as a migratory corridor and grazing area,
c) Maintain and/or increase forage fish production as prey for neighboring salmon populations
d) Provide for connectivity of habitats; also, adequate prey resources, marine foraging areas, and migratory corridors for juvenile, sub-adult and adult Chinook and summer chum for populations from within the main basin (e.g., central Puget Sound sub-basin).

Realized function for listed salmon and bull trout

Fry migrant Chinook – Although South Sound has no natal estuary for an independent population of Chinook and little eelgrass due to its naturally large tide range, 60 percent of the area of the sub-basin is in the nearshore and it has a higher density of pocket estuaries than most other sub-basins (Figure E-10.2). The opportunity exists for fry migrants to derive function from the shallow water, low velocity habitats, but is limited mostly to a few regions within five and 10 miles of the Nisqually estuary (e.g., several pocket estuaries along the west shoreline of Anderson Island, southern Key peninsula and Thurston County shoreline southeast of Johnson Point). These pocket estuaries are nested within mostly protected shorelines and are available and utilized by the non-natal fry migrants from the Nisqually population. A majority of these proximate pocket estuaries are estimated to be properly functioning, providing juvenile salmon functions such as feeding and growth, refuge, areas of physiological transition.

Connectivity between habitat types and landscape classes, including intact freshwater “lenses” (or bands) along shorelines, is essential for small-sized fry migrants emerging from the Nisqually estuary in search of pocket estuaries in the south sound sub-basin. Any disruption such as habitat fragmentation or reduction/elimination of freshwater contribution in areas between the estuary and destination pocket estuaries would be detrimental to the non-natal fry migrants. For example, the reduction or loss of freshwater “seeps” along shorelines due to the loss/reduction of groundwater recharge because of stormwater re-routing to the sound via pipes may prevent fry migrants from reaching pocket estuaries. This activity could jeopardize the fry migrant life history type.

Delta fry Chinook – As a matter of proximity, the opportunity exists for delta fry from the Nisqually population to derive function (rearing, osmoregulatory function, migratory corridor and predator avoidance (refuge)) from the protected shoreline habitats of this sub-basin. On average, delta fry are an abundant Chinook salmon life history type in Puget Sound. As with fry migrants, connectivity between habitat types and landscape classes is essential, and shallow water, low velocity regions are very important. Delta fry moving out of the non-natal Nisqually estuary environment (as larger fish) can access pocket estuaries to the northwest (Case Inlet region) as well as several inlets to the west. Just over one-third of the sub-basin's shorelines are armored, but as delta fry grow to larger sizes and migrate throughout this sub-basin more frequently, the fish are exposed to many regions with wastewater discharges, an increasing occurrence of low dissolved oxygen (Budd Inlet, Case Inlet), elevated water temperatures (Budd Inlet) and a concentrated region of chemical pollution (Budd Inlet) (Figure F-3). In addition, "resident" fish from this and other sub-basins (central Puget Sound and Carr-Nisqually Inlet) are experiencing higher toxic contaminant body burden levels versus those salmon migrating through these sub-basins from elsewhere (WDFW, unpublished data). Finally, the current level of shoreline development places the unique character of this sub-basin and associated functions for salmon at risk.

<ins>Parr migrant Chinook</ins> – Many of the Puget Sound Chinook salmon migrate to the ocean as sub-yearlings (Myers et. al., 1998), and on average this life history type is the most abundant in Puget Sound. The opportunity exists for parr migrants from the non-natal Nisqually population to utilize shoreline habitats within this sub-basin, and connectivity between habitat types and landscape classes is essential to this life history type. Parr migrants moving northwest out of the Carr-Nisqually sub-basin are thought to greatly utilize, and depend on many of the shoreline habitats within the South Sound sub-basin. As larger juveniles make their way through the region, they will encounter *properly functioning* pocket estuaries clustered near Squaxin Island and Totten Inlet, and *at risk* and *not properly functioning* pocket estuaries spread throughout the remaining sub-basin (except for most of Budd Inlet where none are identified). Parr migrants will encounter heavily armored shorelines in Budd Inlet, Eld Inlet, Hammersley Inlet and portions of Case Inlet, as well as the other stressors described above. The toxic contaminant situation described above also presents a problem for this life history type. As mentioned above, the current level of shoreline development places the unique character of this sub-basin and associated functions for salmon at risk.

<ins>Yearling Chinook</ins> – Any reduction in capacity as a result of non-support of the other life history types (i.e., primarily parr migrants) within this sub-basin will negatively affect yearling migrants. Yearlings emigrating from the non-natal Nisqually population, as well as from other populations around Puget Sound, can derive some function (e.g., foraging, refuge, migratory pathway) from the many pocket estuaries and stretches of protected shorelines. Other regions of this sub-basin require attention and some restoration activities (e.g., Budd Inlet). Connectivity between habitat types and landscape classes in South Sound is very important to yearlings from all non-natal populations moving about broadly within Puget Sound. Yearling migrants will be exposed to the same types of stressors and ramifications as described in the other sections above. Of concern are the toxic contaminants polluting the food web in the three southern sub-basins, and the body burden effects on salmon.

<ins>Sub-adult and adult Chinook</ins> - Larger fish migrating through this sub-basin must contend with water quality issues and toxic contaminants in the food chain. Researchers from WDFW have documented that, in general, Chinook salmon living in or migrating through Puget Sound (specifically in central and south sound) are more contaminated with PCBs than stocks outside of Puget Sound (e.g., Columbia River, WA coast). See Figure 4.7 in Section 4. Residence time in

the central and southern Puget Sound basins is suspected as a “primary predictor of PCB concentration in Chinook salmon” and as such, those salmon spending the greatest amount of time in central and south sound exhibit the greatest PCB concentrations (WDFW, unpublished data) (Figure 4-8). Another toxic contaminant of concern in Puget Sound is PBDEs, a common chemical that, like PCBs, are found in greater concentrations in resident Chinook salmon versus migratory Chinook salmon.

Listed summer chum – We hypothesize that none of the eight populations of the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum ESU targeted for recovery use this sub-basin.

Anadromous bull trout – We hypothesize that bull trout do not use this sub-basin.

Table 6-22. Recommended protection actions for South Sound

Protection action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Protect against water quality degradation		Sustained growth and migratory functions	Sustained growth and migratory functions for other species
Protect pocket estuaries in the eastern third of the sub-basin to support the Nisqually population (west shoreline of Anderson Island, southern Key peninsula and Thurston County shoreline southeast of Johnson Point).		Sustained feeding, growth, refuge and migratory functions for other populations, especially Nisqually population	Sustained feeding, growth, refuge and migratory functions for other species
Aggressively protect functioning drift cells that support depositional features throughout the sub-basin but in particular along the west shoreline of Key peninsula, Hartstene Island, east shoreline of Budd Inlet, all of Totten and Skookum inlets, Oakland Bay and outer Hammersly Inlet (Shoreline Protection Target Areas 4, 6, 7, 9and 12 in Fig. E-11.5). Designate these shorelines for the highest level of protection within shoreline master programs and critical areas ordinances and pass strong policies limiting increased armoring of these shorelines.		Sustained feeding, growth, refuge and migratory functions	Sustained feeding, growth, refuge and migratory functions for other species
Protect small freshwater tributary regions, especially those that support mudflat structure through deltaic processes (Upland Sediment Source Protection Targets 1,2,3, 13 and 14 in Fig. E-11.5)		Sustained feeding, growth, refuge and migratory functions for other populations, especially Nisqually population	Sustained feeding, growth, refuge and migratory functions for other species
Protect against catastrophic events		Sustained growth and migratory functions	Sustained growth and migratory functions for other species

Table 6-23. Recommended improvement actions for South Sound

Improvement action	Benefit to Natal Chinook	Benefit to Other (non-natal) Chinook	Benefit to summer chum, bull trout, other fish
Add enhanced treatment for stormwater discharging directly to Puget Sound to the same standards as for salmon bearing streams		Improved growth and migratory functions	Improved growth and migratory functions for other species
Consider wastewater reclamation and reuse retrofits for LOTT and Shelton wastewater discharges		Improved growth and migratory functions	Improved growth and migratory functions for other species
Aggressively promote shellfish environmental codes of practice		Improved feeding, refuge and migratory functions	Improved feeding, refuge and migratory functions
Encourage voluntary re-vegetation of cleared residential shorelines throughout the sub-basin		Improved feeding, growth, refuge and migratory functions	Improved feeding, growth, refuge and migratory functions for other species
Restore tidal influence to the historic Deschutes estuary (Capital Lake)		Sustained feeding, growth, refuge and migratory functions for other populations, especially Nisqually population	Sustained feeding, growth, refuge and migratory functions for other species
Restore pocket estuaries in the eastern third of the sub-basin to support the Nisqually population (west shoreline of Anderson Island, southern Key peninsula and Thurston County shoreline southeast of Johnson Point).		Sustained feeding, growth, refuge and migratory functions for other populations, especially Nisqually populations	Sustained feeding, growth, refuge and migratory functions for other species

7. PROPOSED RECOVERY GOALS AND STRATEGIES

Scott Redman, Puget Sound Action Team
… (??)

This section describes an array of goals and objectives for nearshore and marine aspects of salmon recovery in Puget Sound and describes strategic approaches that we believe are best suited to frame our recovery actions. We have reserved discussion of recovery goals for this point in this document because our thinking about desired outcomes has been informed by the material presented in earlier sections, including the geographic evaluation of sub-basins in Section 6.

This presentation of proposed recovery strategies is intended to demonstrate that (1) are consistent with the hypotheses presented in Section 5, (2) follow from the results of the sub-basin evaluations presented in Section 6, and (3) represent a logical and focused approach to achieving our goals and objectives.

The statements of goals and strategies proposed in this section have not been vetted beyond the small group of people who developed this document. We appreciate that development of goals and strategies should be undertaken in broad collaboration with affected parties. Therefore, we suggest that the goals, objectives, and strategies introduced in this section be considered as straw-man proposals that can be used to initiate and facilitate discussion and development of consensus policy statements on these issues.

7.1 Recovery goals and objectives

In Section 1, we introduced a set of goal statements identified in mid-2004 by a Nearshore Policy Group that PSAT and Shared Strategy convened to assist with development of this chapter. Those statements actually prescribe a strategy to achieve the outcomes we desire related to nearshore and marine ecosystems for salmon and bull trout. This subsection steps back a bit in the strategy development process to articulate desired outcomes as the goals and objectives for the regional nearshore and marine aspects of Puget Sound salmon and bull trout recovery. We are suggesting goals and objectives related to improvements in three different realms:

- viability of salmon and bull trout populations and functioning nearshore and marine ecosystems to support them;
- confidence that strategies and actions are well targeted to accomplish recovery; and
- stewardship of nearshore and marine ecosystems to benefit salmon recovery

Our proposed goal statements represent desired long-term outcomes. Objectives under various goals might be short-term (e.g., next biennia or next decade) or long-term. Some proposals are specific about the temporal nature of the desired outcome, others are not specific but should be refined through future discussions.

7.1.1 Goals and objectives for salmon and bull trout populations and nearshore and marine ecosystems

The subsections below identify overarching goals and more detailed objectives for salmon and bull trout populations and nearshore and marine habitats and ecosystem processes.

(1) Salmon and bull trout populations

One overarching goal is to achieve viable salmon and bull trout populations. Attaining this goal will require contributions from across this recovery plan (not just this chapter). Nearshore- and marine-specific objectives for chinook and Hood Canal summer chum salmon and the region's marine migrant bull trout include:

> Chinook abundance and productivity: Increased numbers of outmigrant juvenile chinook and improved marine productivity of chinook. The co-managers' analysis of planning targets for outmigrants and spawners TRT (2002) [S9]suggests that the desired future condition includes increased abundance of outmigrant juveniles (2 to 28 times recent levels) and, for many populations, increased marine productivity (no change to a 5-fold improvement). Specific objectives would be to establish a recovery trajectory in 10 years consistent with the longer-term attainment of the co-manager's stated targets for abundance and implied targets for marine productivity.
>
> Co-managers' analysis presented by the TRT (2002) suggests the magnitude of change in abundance of juvenile outmigrants to achieve planning targets range from 2 to 28 times recent average abundances.[1] A portion of this range reflects differences across populations and a portion reflects the effect of variable assumptions about (recruit to spawner) productivity on abundance targets. For example, abundance targets for the low productivity situation are 28 times recent averages for the North Fork Nooksack population but only 3 times recent averages for Puyallup and Nisqually populations. If we shift to the high productivity situation, the magnitude of change for abundance of the North Fork Nooksack population is reduced to 20 times recent averages.
>
> We derived estimates of recent and anticipated future marine productivity for eight of 22 populations using the co-managers analysis presented by the TRT (2002). Spawner-to-outmigrant ratios for recent averages presented by the co-

[1] This magnitude of change reflects analysis of 8 of 22 independent populations in five natal river systems. Magnitude of change in outmigrant abundance desired in other systems may not be within this range. For instance, the TRT (2002) suggests the abundance of spawners may not need to increase over recent average levels; this may imply that no increase in outmigrants is needed in this system.

managers fall in the range of 0.3 to 1.1 percent. These ratios are not held constant in the planning targets, where the spawner-to-outmigrant ratios calculated from the values provided by the co-managers range from 0.4 to 3.5 percent. This implies that the co-managers anticipate an improvement in outmigrant-to-spawner productivity for some populations. It is not clear how much of this desired improvement might be attributed to improved conditions in Puget Sound nearshore and marine environments.

- Chinook life history diversity: Maintain chinook life history diversity with increased support for fry that rear in nearshore environments.

- Chinook spatial structure: Maintain chinook spatial structure by supporting nearshore and marine rearing and productivity in each sub-basin.

- Hood Canal Summer Chum -- ?

- Bull Trout -- Maintain the current distribution of bull trout anadromy and restore migratory life history forms in some of the previously occupied areas. Maintain stable or increasing trends in abundance of bull trout. These are two of three objectives listed in USFWS (2004) bull trout recovery plan.

(2) Nearshore and marine habitats and ecosystem processes

A second overarching goal is to achieve and maintain nearshore and marine conditions that support recovery of the region's salmon and bull trout populations. Near-term progress toward this long-term goal might be focused on the following objectives:

- Maintain the functioning of shallow, fine substrate features in and near 11 natal estuaries for chinook (to support rearing of fry).

- Maintain migratory corridors along the shores of Puget Sound .

- Maintain the production of food resources for salmon.

- Maintain functioning nearshore ecosystem processes (i.e., sediment delivery and transport; tidal circulation) that create and support the above habitat features and functions.

- Increase the function and capacity of nearshore and marine habitats to support key needs of salmon.

- Restore and maintain suitable habitat conditions for anadromous bull trout life history stages and strategies. This is a paraphrase of one of three objectives listed in USFWS (2004) bull trout recovery plan.

Progress toward these objectives might be assessed by evaluating status and trends of the following conditions in 10 years relative to the current situations for:

- drift cell processes (including sediment supply, e.g., from feeder bluffs, transport, and deposition) that create and maintain nearshore habitat features such as spits, lagoons, bays, beaches;
- estuarine habitats of major river mouths;
- spawning areas and critical rearing and migration habitats for forage fish;
- shallow, low velocity, fine substrate habitats along marine shorelines, including eelgrass beds and pocket estuaries, especially adjacent to major river deltas;
- freshwater sources that directly affect estuaries and marine shorelines and processes that control the delivery rate and chemical and sediment content of freshwater; and
- riparian areas

7.1.2 Goals and objectives related to confidence in nearshore and marine contributions to recovery

In light of the combined urgency, importance, potential expense, and uncertainty of nearshore and marine aspects of salmon recovery, a third overarching goal is to increase our and others' confidence that recovery actions and ecosystem conditions are supporting salmon recovery.

Progress toward this goal of increased confidence might be focused on the following objectives:

- Increased scientific understanding of relationships between viability of salmon and bull trout populations, nearshore and marine habitat conditions, and habitat management actions. This might be measured by progress over 10 years' time to develop (and publish) and use quantitative models of the effects of habitat alterations on salmon population viability.

- A commitment to acquire and use new information to revise and adapt recovery efforts. This might be measured by implementation over 10 years' time of an adaptive management cycle including revisions to recovery hypotheses, goals, and/or strategies and adaptation of recovery actions.

- Assurance that land development activities and individual and institution behaviors protect functioning habitats and processes. This might be measured by positive changes seen in the effectiveness of regulatory programs as demonstrated through periodic reviews over 10 years' time,

- Positive trends in measures of ecosystem functions and processes and productivity salmon and bull trout populations in nearshore and marine environments. Specific measures related to this outcome are discussed above in Section 7.1.1.

7.1.3 Goals and objectives for stewardship of nearshore and marine ecosystems

A final overarching goal is that Puget Sound citizens and institutions will develop a commitment to stewardship of nearshore and marine ecosystems and that this commitment will be demonstrated through development, land management, and personal and institutional behaviors that support salmon recovery.

Progress toward this goal of increased stewardship might be focused on:

- Broad engagement in recovery efforts and stewardship:
  - Recovery planning represents all key stakeholders and specifies a reasonable breadth of actions and implementers. This can be assessed by review of recovery plan processes and deliverables.
  - Number of people thinking salmon as an influence on their behaviors. This might be assessed by (periodic social research of) trends in attitudes, values, and behaviors.
  - Stakeholders commit or agree to discuss conditions and commitments. This can be assessed by review of recovery plan processes and deliverables.
- Individual and collective decisions that consider nearshore and marine habitat needs of salmon while also supporting other interests
  - Individuals and organizations evaluate the region's well-being based on condition of ecosystem processes, habitats, salmon, biodiversity, and other species. This might be measured by trends in the popular use (e.g., in the media) of broad measures of well-being (e.g., the indicators developed and tracked by Northwest Environment Watch).
  - Public discourse (e.g., in editorials and letters to editor, in challenges to land use decisions) shifts from discussion of protecting property rights to acknowledgement of the constraints of salmon-appropriate behavior within the scope of one's rights.
  - Consideration of long-term effects of actions and public interests in natural resources and privately owned properties. This might be assessed by (periodic social research of) trends in attitudes, values, and behaviors.

7.2 Recovery Strategies

Building from the goals and objectives enumerated earlier in this section, the hypotheses presented in Section 5, and the results of geographic analyses presented in Section 6, we propose an array of strategic approaches for nearshore and marine aspects of salmon recovery that we suggest could form the basis for identification of specific recovery actions. This subsection names our strategies and explains how we believe they derive from our hypotheses and how they will help us achieve our goals and objectives.

7.2.1 Protect functioning habitat and high quality water commensurate with the support provided for salmon and bull trout.

The first major strategic approach is to protect current levels and types of functions for salmon and bull trout. Elements of this strategic approach are itemized in Table 7.1. These strategies help achieve the goals and objectives for maintaining conditions of nearshore and marine ecosystems, improved confidence in recovery, and improved stewardship. Protection efforts will not be sufficient to improve salmon and bull trout viability or to increase functioning of nearshore and marine habitats for these fish but they are a logical prerequisite for more aggressive habitat actions and help preserve options for future adaptations of recovery efforts.

Efforts to implement this strategy will involve various authorities, decisions, and commitments, each of which will require a balance between commitment to habitat protection (to support salmon recovery) and other interests in marine shorelines (e.g., residential or commercial development).

7.2.2 Improve the function of habitats by strategic and locally-acceptable actions to restore, rehabilitate, or substitute for natural ecosystem processes

Nearshore and marine habitat improvements appear to be needed in many areas of Puget Sound to increase the capacity of nearshore environments to support more abundant outmigrant juveniles and increase the marine productivity of select populations. Therefore, strategic efforts to restore, rehabilitate, or substitute for nearshore and marine processes and conditions represent our second major recovery approach. Table 7.2 details proposed elements of this strategic approach.

Restoration, rehabilitation, and substitution efforts will help us achieve our goals of increased viability of populations, increased function of nearshore and marine habitats, increased confidence in recovery, and increased stewardship.

Restoration or rehabilitation of tidal exchange processes in river mouth estuaries is occurring at many locations around Puget Sound (e.g., Nisqually, Skagit, Skokomish, Snohomish, and Jimmycomelately estuaries). Through these experiences we feel rather certain that such projects can and do affect processes. Substantial questions remain, however, about the effects of such actions on salmon and bull trout viability. Other types of improvements as detailed in Table 7.2 are less well proven and understood. Where these types of projects are pursued and implemented, we would expect that there could be considerable information developed about the effectiveness of these projects in restoring processes and affecting salmon and bull trout viability.

7.2.3 Conduct research, monitor conditions and actions, and evaluate recovery actions to support the refinement of management strategies and actions

As discussed earlier in this section and throughout this document, recovery of salmon, protection of functioning nearshore and marine habitats, and effective restoration of nearshore habitats or processes are all uncertain propositions. Therefore, we propose a third major strategic approach: collect and evaluate information to support future refinements to recovery hypotheses, goals and objectives, strategies, and actions. Strategic elements of this approach are identified in Table 7.3. All address the goal of increasing confidence in recovery.

Table 7.1: Protection of Functioning Habitat and High Water Quality

Strategy	Goals and objectives addressed	Relation to hypotheses and sub-basin evaluations
Implement existing voluntary and regulatory protection programs to maintain functions for salmon and bull trout	Maintaining nearshore and marine conditions that support recovery Increased stewardship – related to opportunities for voluntary actions by a large number of landowners	Protection targets are identified in hypotheses 4 & 5 and in sub-basin evaluations[1] Stressors to be addressed to protect functions are suggested by hypothesis 7 and specifically identified in sub-basin evaluations[2]
Evaluate effectiveness of existing programs	Increased confidence in recovery – related to assurance that recovery actions are effective	Protection targets identified in hypotheses 4 & 5 and in sub-basin evaluations Stressors to be addressed to protect functions are suggested by hypothesis 7 and specifically identified in sub-basin evaluations
As needed, design and implement refinements (including voluntary and regulatory innovations) to achieve protection of functions	Maintaining nearshore and marine conditions that support recovery Increased confidence in recovery – related to assurance that recovery actions are effective Increased stewardship – related to opportunities for voluntary actions by a large number of landowners	Protection targets identified in hypotheses 4 & 5 and in sub-basin evaluations Stressors to be addressed to protect functions are suggested by hypothesis 7 and specifically identified in sub-basin evaluations Preference for process-based protection is specified in hypothesis 8.
Regionally-focused organizations and local communities should collaborate to prevent catastrophic events and/or protect nearshore habitat features from catastrophic events[3]	Maintaining nearshore and marine conditions that support recovery (and increased viability of salmon and bull trout) Increased confidence in recovery – related to relative assurance that major events might be avoided or quickly remediated.	Protection targets are identified in hypotheses 4 & 5 and in sub-basin evaluations Stressors to be addressed to protect functions are suggested by hypothesis 7 and specifically identified in sub-basin evaluations

[1] Add some specifics here from Section 6?
[2] Add some specfics here from Section 6?
[3] Prevention and protection should be targeted to reduce risks in susceptible areas (as defined by vessel traffic, storm conditions, response constraints, and other risk factors); key nearshore environments such as natal estuaries for salmon and forage fish spawning areas; and major migratory routes such as Admiralty Inlet, Tacoma Narrows, Deception Pass and the San Juan Islands.

Table 7.2: Improve the Function of Nearshore Habitats by Restoration, Rehabilitation, or Substitution

Strategy	Goals and objectives addressed	Relation to hypotheses and sub-basin evaluations
Pursue and implement locally acceptable projects to improve tidal exchange processes in river mouth estuaries	Achieving and maintaining nearshore and marine conditions that support recovery Increased viability of Chinook – especially by support for sensitive life history trajectories – and other salmon and bull trout Increased confidence in recovery from: information about effects on viability; assurance that sensitive life history trajectories receive support	Restoration of tidal exchange processes derives from hypotheses 1, 2, 4, and 8. Opportunities for improved tidal exchange are identified in sub-basin evaluations.[1]
Pursue and implement locally acceptable projects to improve the function of marine shorelines, particularly pocket estuaries, eelgrass beds, and other shallow, low velocity, fine substrate habitats adjacent to major estuaries	Achieving and maintaining nearshore and marine conditions that support recovery Increased viability of Chinook – especially by support for sensitive life history trajectories – and other salmon and bull trout Increased confidence in recovery from: information about ability to restore function and to affect viability; assurance that sensitive life history trajectories receive support Increased stewardship – related to opportunities for actions by a large number of landowners	Restoration of shoreline conditions adjacent to major estuaries derives from hypotheses 1, 2, 4, and 8. Opportunities for improved shoreline function are identified in sub-basin evaluations.[2]
Pursue and implement locally acceptable projects to improve sediment delivery from sources such as feeder bluffs, river and creek discharges, and sediment transport processes to support habitat formation and function	Achieving and maintaining nearshore and marine conditions that support recovery (and increased viability of salmon and bull trout) Increased confidence in recovery from information about ability to restore function and to affect viability Increased stewardship – related to opportunities for actions by a large number of landowners	Restoration of sediment delivery derives from hypotheses 1, 2, 4, and 8. Opportunities for improved sediment delivery are identified in sub-basin evaluations.[3]

[1] Add detail from Section 6?
[2] Add detail from Section 6?
[3] Add detail from Section 6?

Strategy	**Goals and objectives addressed**	**Relation to hypotheses and sub-basin evaluations**
Pursue and implement locally acceptable projects to improve marine riparian functions related to water quality, food production, and refuge	Achieving and maintaining nearshore and marine conditions that support recovery (and increased viability of salmon and bull trout) Increased confidence in recovery from information about ability to restore function and affect viability Increased stewardship – related to opportunities for actions by a large number of landowners	Restoration of marine riparian functions derives from hypotheses 1, 2, 4, and 8. Opportunities for improved sediment delivery are identified in sub-basin evaluations.[1]
Facilitate the development and implementation of restoration programs and projects to support improvements in all sub-basins of Puget Sound	Increasing viability of Chinook salmon – by support for spatial structure Increased confidence in recovery from assurance that spatial structure receives attention	Restoration in all sub-basins derives from hypothesis 5.

[1] Add detail from Section 6?

Table 7.3: Research, Monitor, Evaluate, and Refine Hypotheses, Goals, and Strategies

Strategy	Goals and objectives addressed	Relation to hypotheses and sub-basin evaluations
Conduct studies and collect information to test hypotheses about nearshore and marine ecosystem processes and to evaluate the effects of strategies and management actions on nearshore and marine ecosystems	Increased confidence in recovery from evidence of effectiveness, support for hypotheses, and/or assurance of commitment to adaptation.	Would test hypotheses 1, 2, and 8. Would provide for evaluation of implemented actions
Designate and initiate studies of an intensively monitored shoreline to focus and organize efforts to test hypotheses about effects of shoreline ecosystems (and shoreline restoration) on salmon viability	Increased confidence in recovery from evidence of effectiveness, support for hypotheses, and/or assurance of commitment to adaptation.	Would test hypotheses 3, 4, 5, and 6.
Use the intensively monitored Skagit Delta to organize studies to test hypotheses about effects of estuaries (and estuary restoration) on salmon viability	Increased confidence in recovery from evidence of effectiveness, support for hypotheses, and/or assurance of commitment to adaptation.	Would test hypotheses 3, 4, 5, and 6.
Conduct studies to test hypotheses about the effects of stressors/threats on salmon individuals, life history trajectories, and populations	Increased confidence in recovery from evidence of effectiveness, support for hypotheses, and/or assurance of commitment to adaptation.	Would test hypothesis 7.
Convene management conference to refine hypotheses and adapt strategies and actions	Increased confidence in recovery from assurance that strategies and actions will be re-directed based on new information	Would suggest revision of hypotheses and sub-basin evaluations.

8. TOWARD AN ADAPTIVE ACTION PLAN

Management of nearshore and marine environments to support recovery of salmon and anadromous bull trout in the Puget Sound region will require specific actions following the strategies described in Section 7. Given the considerable uncertainties about the effects of nearshore and marine actions (and collections of actions) on salmon and bull trout individuals, life history strategies, populations and ESUs, we believe that these actions must include, and be designed around, a commitment to an ongoing adaptation of management efforts through systematic learning. A commitment to adaptive management provides the best available assurance that the strategies of protecting existing habitat function and continued learning about salmon and bull trout interactions with nearshore and marine environments will preserve options for future course corrections and, over time, improve our and others' confidence that Puget Sound's nearshore and marine environments are supporting the viability of the region's salmon and bull trout.

In this section, we propose a collaborative process that Shared Strategy and/or successor institutions could lead over the next six to eighteen months to develop an adaptive action plan that would describe how nearshore and marine aspects of salmon recovery would be coordinated and adapted over the first 10-years of recovery effort.

We have not attempted to include a 10-year action plan in this document because our work to develop the technical basis for our recovery hypotheses and strategies has continued into April 2005. It is only in delivering this document to Shared Strategy and the TRT (in early May 2005) that we feel we have sufficiently developed and presented the technical foundation around which decision-makers could discuss and move toward commitments to take specific actions following the strategic approaches introduced in Section 7. A key next step is to pursue this collaborative discussion.

The subsections below suggest a series of discussions and decisions that follow the adaptive management planning approach (and the specific guidance and terminology) suggested by the Ecosystem Management Initiative (EMI) of the University of Michigan's School of Natural Resources and Environment. (For details and definitions of terms please see EMI's web site at www.snre.umich.edu/emi/evaluation.) Consistent with the philosophy of Shared Strategy and the decision-makers' discussion mentioned in the paragraph above, EMI emphasizes a collaborative approach to planning.

8.1 Convene the right people to develop an adaptive action plan

Shared Strategy (staff, development committee, and/or work group) should decide the scope of participation in policy discussions and decisions about actions, commitments to actions, and design of an adaptive management framework related to nearshore and marine aspects of salmon recovery in Puget Sound. As indicated in Section 1, we believe that identification of region-scale priorities and actions must address issues beyond nearshore and marine aspects of salmon recovery. Therefore, we suggest that a regional decision-making institution of greater scope than the Nearshore Policy Group that PSAT and Shared Strategy staff convened through early 2004 be assigned the tasks depicted below.

EMI (2004) suggests that involving many groups improves credibility and ensures the broadest possible joint understanding of the situation and selected strategies. EMI (2004) suggests candidates to involve in adaptive action planning should include those who:

- have an interest in nearshore and marine aspects of salmon recovery and care about actions and adaptations that might be selected;
- are responsible for decision-making;
- have evaluation or adaptive management experience or expertise; and/or
- are good coordinators or enthusiastic leaders.

We suggest that the development committee of Shared Strategy and/or a successor institution be considered as the nucleus for the plan development activities suggested below. Additional membership may be needed to ensure that affected entities (e.g., counties, cities with marine shorelines) and adaptive management experts (e.g., from TRT or elsewhere) are sufficiently represented in discussions and decisions.

8.2 Describe the situation

The first stage in strategic planning and adaptive management planning is to develop a consensus view of what we are trying to achieve with efforts to address regional nearshore and marine aspects of salmon recovery in Puget Sound (EMI 2004[S10]). We recommend that the group that develops an adaptive action plan to address nearshore and marine aspects of salmon recovery should be briefed on and familiar with the material presented in this document, especially the hypotheses stated in Section 5, the sub-basin recommendations developed through the various parts of Section 6, and the strategies described in Section 7.

Figures 8.1 and 8.2 *(provided in a separate file)* present two versions of a visual diagram – which EMI (2004) calls a situation map – of the relationships between the goals and strategies we presented above in Section 7. This diagram also illustrates how these strategies and goals relate to assets and threats, which are external circumstances that affect progress toward our goals. Figure 8.1 presents a simplified version of this diagram – showing only titles of strategies and general statements of goals. We hope that this version will help orient the reader to the general design of this diagram and set the stage for review of Figure 8.2, which adds detail about relationships between elements of the strategies and objectives associated with each of the goals.

An initial meeting(s) of the adaptive action planning group could include review Figures 8.1 and 8.2; discussion and clarification of the underlying hypotheses, bases for strategies, and key uncertainties; and suggestions of revisions to the diagrams to represent the group's consensus views.

8.3 Initial suite of actions and framework for assessment

In this subsection, we combine the second stage of EMI's (2004) adaptive management planning process with a collaborative effort to define the suite of actions that should be implemented to support nearshore and marine aspects of salmon recovery. This stage is the heart of the adaptive action planning process in which a consensus view will be developed about:

- the actions to undertake and
- the questions to answer through evaluation of actions (and the measures needed to provide answers)

8.3.1 What do we know and want to know about implementation and effectiveness?

EMI (2004) suggests a series of brainstorm sessions of the adaptive management planning group to get started with this stage. Because we expect the adaptive action planning process to also define the suite of actions to be implemented we elaborate on EMI's suggestions for three sessions:

- How close are we to achieving our objectives? During this session(s) the group would share ideas and then work toward consensus thinking about where we are relative to our objectives for nearshore and marine ecosystems, salmon viability, knowledge, and stewardship. We foresee two outcomes from this discussion: (1) a list of possible evaluation questions that ask how close we are to our objectives and (2) consensus insights about the relative distance between the current situation and our various objectives.

- How effective are current applications of our strategies at reducing threats, using assets, and accomplishing objectives? During this session(s) the group would discuss and come to common understandings about how we know or could know whether: threats identified in Section 4 are decreasing; Section 7 protection and restoration strategies reduce threats; we capitalize on and maintain currently functioning habitats and processes, institutions, and other assets; and we understand possible unintended consequences of protection and restoration actions. Again, we foresee two outcomes from this discussion: (1) a list of possible evaluation questions that ask how effectively our strategies address threats and leverage assets and (2) consensus insights about relative merits, uncertainties, and risks of our various strategies.

- Are actions implemented as planned? During this session(s) the group would discuss: how we might evaluate whether we are accomplishing actions; how efficiently we implement actions; and whether we have the information, staff, funding, and other resources to complete restoration, protection, and science activities. For this session we also foresee two outcomes: (1) a list of possible evaluation questions that ask how well we implement actions and (2) consensus insights about whether current efforts to advance our strategies are implemented as planned.

8.3.2 What should we do over the next 10 years?

Using the (second) outcome of the three sessions described in section 8.3.1, we suggest that the group should engage the question of: what actions seem warranted over the next 10 years? During this session(s) the group would brainstorm and then develop consensus about a list of actions that advance the strategies enumerated in Section 7 and seem reasonable given what we know about available resources and competing interests and relative priorities across the region. Possible actions to consider during this session include the recommendations listed in Section 6 and region-wide suggestions presented in Tables 8.1, 8.2, and 8.3.

8.3.3 What evaluation questions are most useful to answer?

To narrow the list of evaluation questions that will be addressed through the adaptive action plan, we suggest that the planning group follow the priority-setting process described by EMI (2004). In this process, the planning group is first asked to identify the priority objectives and then to define the key questions that they have about that (those) objective(s) and the strategies, threats, or assets that influence that (those) objective(s). The goal of this step is to identify the most important evaluation questions that should be addressed by the adaptive management portion of the 10-year action plan. The narrowed list of evaluation questions should items from each of the three types of questions asked in Section 8.3.1. We present a sample list of evaluation questions in Table 8.4; this table might be useful to the adaptive action planning efforts described in sections 8.3.1 or in this section.

8.3.4 What will be measured to answer evaluation questions?

The next step suggested by EMI (2004), is to identify specific indicators (including comparisons to other times, other places, etc) to provide answers to the key evaluation questions. We recommend that the adaptive action planning group proceed to this step with the advice of the state's Monitoring Forum, the Puget Sound Ambient Monitoring Program, and/or other established entities charged with understanding and coordinating the variety of information collection efforts already underway in the region. The specific information needed to address the priority evaluation questions might be collected in other programs or may need to be commissioned for the adaptive management purposes of regional salmon recovery. Indicator selection is complex; we recommend that specific measures be developed by iterative discussions among the action planning group and technical specialists who are well versed in what is currently and/or feasibly collected.

8.3.5 How might the evaluation information be used?

The final step in developing the initial framework for evaluation and adaptive management is to contemplate and brainstorm how indicator information might be used.

This process will help group members clarify how they envision evaluation information might influence management decisions. For each selected evaluation question, the group should be able to identify one or more possible uses of the information to help confirm that the question, and the approach to answering it, will be useful in decision-making

8.4 Logistics of adaptive management

We bundle the last two stages of the EMI (2004) evaluation approach under the heading logistics of adaptive management. In this section we propose a set of steps for a planning group to decide what information collection and analysis activities are necessary and how they will be accomplished (EMI's Stage C) and how information and analyses will be used to refine and adapt hypotheses, strategies, and actions (EMI's Stage D).

8.4.1 How will information be collected and analyzed?

Comparable to the assignment in 8.3.2, we suggest that the group should engage the question of: what information will be collected and analyzed to evaluate recovery and support adaptations over the next 10 years? We suggest that during this discussion, the group should seek the advice of the Monitoring Forum, PSAMP, and/or others to get informed about possible collaborations with ongoing information collection and analysis and then discuss and work toward consensus about new and existing information collection and analysis tasks to include in the 10-year action plan. As with other actions, these tasks should be reflected by commitments from implementers and/or a discussion of the conditions needed to obtain commitments.

8.4.2 How will information and analyses be used in decision-making?

Finally, the adaptive action plan will need to describe how new information will be applied to decision-making. In this stage of the process, we follow the EMI (2004) approach in suggesting that the planning group should: (1) select trigger points, (2) decide what actions will be taken, by whom, in response to reaching trigger points, and (3) develop a plan for presenting and summarizing evaluation information.

Selection of trigger points and specification of actions that are triggered clarifies the adaptive contingencies built into the action plan: e.g., if a certain level of bulkheading is reached, a study on the effect of bulkheads on juvenile salmon rearing will be initiated and the permitting authorities will be asked to adjust permit conditions and/or approval processes until study results are available.

We suggest that the planning group clearly establish trigger points, courses of action, and responsibilities for adaptation in an adaptive management plan. This plan should also describe the institutional oversight needed and deployed to ensure that information and analyses are developed, triggers are checked, and adaptive actions are taken.

We suggest the following types of triggers and adaptations be included in the adaptive management portion of the 10-year action plan:

- Update assessment of conditions/status (what reports, by whom & when?)
- Refine hypotheses (whose hypotheses, reviewed how, when?)
- Review and, if appropriate, revise strategies (who & when?)
- Devise and implement new or modified actions (including a new monitoring and adaptive management plan) (who & when?)
- Document adaptations and the adaptive process (investments in monitoring, evaluation, planning) (what report, by whom & when?)

Table 8.1: Possible regional protection actions for a 10-year action plan

Recommended action	**Source**
Ecology ensures that activities subject to state authorities of the Shoreline Management Act are protective of habitat functions for salmon and bull trout by: (1) reviewing shoreline permit applications; (2) permitting and approving appropriate activities and programs; and (3) facilitating compliance with state laws and policies through education, technical assistance, and enforcement actions.	NPG & PSAT Mgmt. Team discussion
WDFW ensures that activities subject to state authorities of the Hydraulic Code are proctective of habitat functions for salmon and bull trout by: (1) reviewing applications for hydraulic project approvals; (2) granting approvals; and (3) facilitating compliance with state laws and policies through education, technical assistance, and enforcement actions.	NPG & PSAT Mgmt. Team discussion
State agencies share example language of local regulations, ordinances, and policies	NPG & PSAT Mgmt. Team discussion
State agencies provide continued guidance on how to integrate shoreline and growth management, including examples for local governments on how to effectively link CAO and SMP updates with salmon recovery	NPG & PSAT Mgmt. Team discussion
State agencies develop and provide guidance to document sources of best available science for nearshore recovery	NPG & PSAT Mgmt. Team discussion
State agencies develop and follow protocols for review of and comment on local policies, plans, ordinances, and other program elements that address growth and shoreline management authorities	NPG & PSAT Mgmt. Team discussion
State agencies review and comment on local policies, programs, ordinances, and regulations to ensure state's expectations for growth and shoreline management (as expressed in statutes and rules) regarding protection of existing functions and consideration of salmonids and bull trout. Comment should recognize the responsibility of local authorities to achieve the balances called for in the state's growth and shoreline management statutes, rules, and policies.	NPG & PSAT Mgmt. Team discussion
NGOs and PSNERP share information about key nearshore and marine habitat features and opportunities for habitat protection and improvement identified through their assessment activities	NPG & PSAT Mgmt. Team discussion
NGOs and state agencies collaborate with local and tribal governments and watershed and salmon habitat groups to devise a coordinated approach to identifying key habitat features, landscapes, and processes at greatest risk for development and designing protection efforts – regulatory and voluntary – to focus in those areas	NPG & PSAT Mgmt. Team discussion
NGOs and governments develop and implement strategies to focus voluntary conservation efforts and funds on the protection of habitats and processes at risk that are not adequately protected by regulations because of landownership or development patterns.	NPG & PSAT Mgmt. Team discussion
Conservation Commission continues targeting of technical assistance and incentive payments to activities to support salmon recovery	NPG & PSAT Mgmt. Team discussion
DNR and leaseholders continue to develop and implement aquatic resource protections through conservation leasing	NPG & PSAT Mgmt. Team discussion
State & federal agencies and NGOs provide funding to support public and private education and outreach programs focused on marine resources and development practices.	NPG & PSAT Mgmt. Team discussion
State & federal agencies and NGOs develop and distribute educational materials targeted to landowners and their opportunities to protect and improve habitat conditions to support salmon recovery.	NPG & PSAT Mgmt. Team discussion
State salmon recovery office facilitates discussion regarding extending or amending Public Benefit Rating System authorities and/or applicability to marine settings.	NPG & PSAT Mgmt. Team discussion
State salmon recovery office facilitates legal and policy discussion to support lot consolidation	NPG & PSAT Mgmt. Team discussion

Recommended action	**Source**
Amend GMA and SMA to describe the role of the local programs and regulations in salmon recovery and to require implementation that is protective of salmon	NPG comments on Sept. 2004 draft
Encourage and review protection actions to ensure that balance of other goals/interests is incorporated into the decision making process	NPG comments on Sept. 2004 draft
Develop, advocate, and implement SMPs, CAOs, and other regulations that protect and restore shoreline with a focus of the highest levels of protection available in local shoreline master programs and/or critical areas ordinances on targets identified in sub-basin evaluations	NPG comments on Sept. 2004 draft
Provide funds to support local governments' regulation, including enforcement, to protect neashore (not just counties)	NPG comments on Sept. 2004 draft
Develop and provide model policies AND guidance on marine shorelines	NPG comments on Sept. 2004 draft
Focus acquisition on sub-standard lots that contain habitat/function priorities	NPG comments on Sept. 2004 draft
Develop and assist in implementation of non-regulatory approaches to local management of shoreline development and growth – e.g., technical assistance to provide incentives for landowners to restore shorelines during redevelopment activities	NPG comments on Sept. 2004 draft
Implement mini-grant and partnership programs as cost-share tools	NPG comments on Sept. 2004 draft
Coordinate mitigation required under the ESA, CWA, SMA, and the Hydraulics Code, etc. to steer mitigation strategically toward the highest needs of the system as opposed to the needs of a site.	NPG comments on Sept. 2004 draft
Move houses (and similar actions) by any approaches from in the land use "toolbox" -- incentives or regulations	NPG comments on Sept. 2004 draft
New information on the presence and distribution of juvenile salmon should be used to review and modify shoreline construction timing and practices throughout the Puget Sound.	NPG comments on Sept. 2004 draft
Ensure enforcement by regulatory agencies	NPG comments on Sept. 2004 draft
Develop clear and numerical guidelines that direct what is (not) allowed with new or re-development	NPG comments on Sept. 2004 draft
Broaden local stormwater management programs to include monitoring and adaptive management; NPDES permits; funding for monitoring, and retrofits	NPG comments on Sept. 2004 draft
Develop and coordinate a public outreach plan, including technical assistance to private property owners and education of children and adults about salmon life cycles and ways in which people can minimize their impacts to salmon	NPG comments on Sept. 2004 draft
Develop clear goals that balance specific GMA and planning targets for economic, transportation and housing development with specific targets for spatial habitat integrity and connectivity	NPG comments on Sept. 2004 draft
Consider wastewater reclamation and reuse retrofits for Bellingham Bay and Semiahmoo Spit wastewater discharges	South Georgia Strait evaluation

Table 8.2: Possible regional restoration actions for a 10-year action plan

Recommended action	**Source**
Encourage SRFB and lead entities to integrate sub-basin recommendations for protection and restoration in their funding decisions and strategies.	NPG comments on Sept. 2004 draft
Implement the Bellingham Bay habitat plan; targeted restoration in Bellingham Bay – per the recommendations of the Bellingham Bay pilot project.	South Georgia Strait evaluation
Restore natural sediment delivery processes in target areas (e.g., near Cherry Point) by removing shoreline armoring and/or retrofitting facilities (e.g., pier) that might disrupt sediment passage	South Georgia Strait evaluation
Begin restoration with public lands	NPG comments on Sept. 2004 draft
Restore the Skagit, Snohomish, Stilliguamish and Nooksack river deltas	NPG comments on Sept. 2004 draft
Encourage and review restoration strategies and actions to ensure that balance of other goals and interests is incorporated into the decision making process	NPG comments on Sept. 2004 draft
Develop and provide substantial incentives to restore key habitats in key places – incentives drive opportunities rather than being driven by them.	NPG comments on Sept. 2004 draft
Encourage use of SMPs as an incremental restoration tool – support local jurisdiction efforts to: coordinate salmon recovery planning into broader shoreline restoration plans; use shoreline restoration plans to inform local SMP updates, including establishing shoreline designations, zoning, and shoreline development regulations; develop non-regulatory programs to implement shoreline restoration plans	NPG comments on Sept. 2004 draft
Develop strategic approach to restoration at local and regional scales to optimize allocation of resources and time	NPG comments on Sept. 2004 draft
Facilitate local restoration of nearshore not just estuaries	NPG comments on Sept. 2004 draft
Reduce or eliminate fees for restoration and enhancement projects	NPG comments on Sept. 2004 draft
SRFB, ALEA, Puget Sound & Adjacent Waters, NOAA Community Based Restoration and other state and federal programs fund and otherwise facilitate projects to increase the tidal prism in natal deltas and select pocket estuaries by removing road constrictions (e.g., I-5, Hwy 101, local shoreline roads)	NPG & PSAT Mgmt. Team discussion

Table 8.3: Possible regional research, monitoring, and evaluation actions for a 10-year action plan

Recommended action	Source
Apply increased knowledge towards decisions and actions	NPG comments on Sept. 2004 draft
Develop quantified target population sizes and numbers of juveniles by sub-basin – adapt plans based on these targets	NPG comments on Sept. 2004 draft
Improve documentation of how the San Juan region is used by migrating salmon (juvenile and adult).	NPG comments on Sept. 2004 draft
Develop more complete information on forage fish spawning & life-history and drift cell protections; comprehensive forage fish spawning surveys may also be a priority in all sub-basins.	NPG comments on Sept. 2004 draft
Develop estimates of costs for specific action items	NPG comments on Sept. 2004 draft
Partner and integrate local environmental monitoring programs with regional programs	NPG comments on Sept. 2004 draft
Fund key research into the scientific basis, per the standards of "best available science," for appropriate marine shoreline buffers and setbacks around the Puget Sound basin	NPG comments on Sept. 2004 draft
Continue studies of salmon use of various nearshore environments, e.g., Skagit System Coop., salmon beaches	NPG comments on Sept. 2004 draft
Examine status of delta fry and fry migrants in central Puget Sound populations	Technical comments on Sept. 2004 draft
Develop models for estuary reconnection that will support access to intertidal wetlands in the Lummi delta for delta fry life history type that may have been part of the historic population	South Georgia Strait evaluation
Conduct studies to better understand the role of eelgrass detritus export to other sub-basins and model expected changes to eelgrass cover and distribution as a result of various delta reconnection scenarios.	Sub-basin evaluations
Research is needed to understand metrics of eelgrass patchiness important to Hood Canal/Eastern Strait of Juan de Fuca Summer chum	Sub-basin evaluations
Attend to food webs (e.g., sufficient bait fish and krill to support migrants and residents; beyond spawning beaches, to stock recovery)	Sub-basin evaluations
Research the geologic and oceanographic processes that determine upwelling of nutrients, primary and secondary productivity that support forage fish and salmon.	Sub-basin evaluations
Examine the role of freshwater outflow in driving deep estuarine circulation need to be better understood.	Sub-basin evaluations

Table 8.4. Possible Evaluation Questions

Are region-wide protection actions implemented? Efficiently? What resources are used or needed?
Are local protection actions implemented? Efficiently? What resources are used or needed?
Are improvement projects implemented as planned? Efficiently? What resources are used or needed?
Are region-wide protection actions effective at maintaining current functions? Are there unintended consequences on salmon viability?
Are local regulatory protections effective at maintaining current functions? Are there unintended consequences on salmon viability? • What is the rate of habitat loss in various jurisdictions? • Group jurisdictions by type of approach • Define levels of "on paper" protection and test whether on the ground results correspond to the "on paper" level
Are local voluntary and incentive-based protection efforts effective at maintaining current functions? Are there unintended consequences on salmon viability? • Do properties in protected status deliver different habitat functions (now & projected into future) than do un-protected properties? • What are the costs per unit (acre, mile) of various programs and (combined with above) what is the cost-effectiveness of various programs?
Are process and habitat improvements effective?
What relationships among salmon/bull trout and habitat protection and restoration are evident at intensively monitored areas (Skagit delta already designated; shoreline to be designated)? • How do competition and predation by hatchery fish affect the viability of wild salmon? • Are any PS salmon capacity limited in nearshore or early marine life stages? • Do restoration, rehabilitation, or substation efforts have detectable effects on measures of salmon viability? Are these the hypothesized effects? • Do the strategies and actions focused on chinook (and chum?) recovery accomplish ecosystem benefits and support recovery of other species?
What do coordinated research programs tell us about relationships among salmon/bull trout and nearshore or marine habitats, processes, and/or stressors? • Nearshore ecosystem processes and the effects of restoration (CHIPS, UW PRISM/nearPRISM) • Are any PS salmon capacity limited in nearshore or early marine life stages? (UW and/or NOAA NWFSC) • Do the strategies and actions focused on chinook (and chum?) recovery accomplish ecosystem benefits and support recovery of other species? • How do competition and predation by hatchery fish affect the viability of wild salmon? (NOAA NWFSC) • Ecotoxicology (contaminant effects) (NOAA NWFSC with USGS divisions)

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Page: 2
[S1]Do we want to add another hypothesis re: the importance of disturbance as another process or as a control on process & habitat?
Page: 5
[S2]There may be an updated version of this figure available from Shared Strategy and/or the TRT.
Page: 7
[S3] The legend and bottom inset box of this figure incorrectly refer to sub-regions. These should refer to sub-basins.
Page: 10
[S4]Need to add Gallagher 1979 to reference list.
Page: 10
[S5]This list of habitat types and features should be reviewed and revised, perhaps using Shorezone to see what other Dethier or other classes are common in bays.
Page: 12
[S6]As with features of bays, this list of habitat types and features should be reviewed and revised to reflect more than intertidal and to be sure we've capture key types of intertidal features.
Page: 1
[S7]Do we want to add another hypothesis re: the importance of disturbance as another process or as a control on process & habitat?
Page: 3
[S8]Do either of these references include empirical evidence of these functions?
Page: 2
[S9]Puget Sound Technical Recovery Team. 2002. Planning ranges and preliminary guidelines for the delisting and recovery of the Puget Sound Chinook Salmon Evolutionarily Significant Unit. April 30, 2002. Tables 1 and 2 labeled as May 8, 2002.
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